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BASIC WASTEWATER TREATMENT

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Basic Gas Chlorination Workshop

Basic Water Treatment Operation

Surface Water Treatment Workshop

Activated Sludge Process Workshop

Wastewater Sludge Technology

Preventive Maintenance Workshop

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INTRODUCTION

The Basic Wastewater Treatment course based on this manual covers five days at the Ministry of the Environment training facilities. The course consists of lecture-discussions and hands-on training in sewage treatment plant operations.

The principal objective of the course is to introduce the operator to the fundamentals of sewage plant operation. The lesson objectives are clearly indicated at the beginning of each topic, and tell the operator exactly what he should know or do after having covered that topic. In order to successfully complete this course, an overall average of 70% is required.

This is a working course in which each person will be expected to take an active part in subject discussions and to acquire as much practical knowledge as possible from the lectures and from the demonstrations presented during the course.

TABLE OF CONTENTS

BASIC SEWAGE TREATMENT

	Topic	Page
1.	WASTEWATER CHARACTERISTICS	
	GENERAL	1
	SOURCES	2
	QUANTITY	4
	QUALITY	5
	Bacteriological Characteristics	5
	Physical Characteristics	5
	Chemical Characteristics	6
	Solids	7
	Biochemical Oxygen Demand	10
	Dissolved Gases	10
	Nutrients	10
	EFFECTS OF WASTE DISCHARGES	12
	Human Health	13
2.	BACTERIOLOGY	
	WASTEWATER TREATMENT OBJECTIVES	1
	To Remove Organic Material	1
	To Eliminate Disease Producing Agents	2
	BACTERIAL STRUCTURE	3
	Size	3
	Shape	3
	Arrangement	3
	BACTERIAL REPRODUCTION	4
	METABOLIC ACTIVITIES AND BACTERIAL GROWTH	5
	Extracellular Enzymes	5
	Intracellular Enzymes	5
	FACTORS AFFECTING GROWTH	6
	Temperature	6
	Oxygen	6
	pH	6
	Food Supply	6

2. **BACTERIOLOGY - Cont'd...**

BACTERIA AND THE WASTEWATER TREATMENT PROCESS . . .	7
Removal of Organic Material	7
ANAEROBIC DIGESTION	8
AEROBIC DIGESTION	9
ELIMINATION OF PATHOGENS	9
SUMMARY	10

3. **PRIMARY TREATMENT**

PUMPING STATIONS	1
FLOW CONTROL	1
Manual Operation	3
Float	3
Bubbler (Pneumatic)	3
Electric (Probes)	4
Flowmatchers	4
Pneumatic Ejectors	5
Sonic Transducers	5
PRELIMINARY TREATMENT	6
SCREENS	6
Coarse Screens	6
Fine Screens	7
Mechanically Cleaned Screens	7
Cleaning Screens	10
Disposal of Screenings	10
SHREDDING DEVICES	11
GRIT REMOVAL UNITS	12
Grit Channels	12
Aerated Grit Chamber	12
Detrition	13
Centrifugal Separators	16
Grit Disposal	17
PRE-AERATION	17

3. PRIMARY TREATMENT - Cont'd...

PRIMARY TREATMENT	18
Clarifier Operation	19
Scum Removal	23
Chemical Precipitation	23
Flotation Processes	23
WASTE STABILIZATION PONDS	24
DESIGN CRITERIA AND CONSTRUCTION DETAILS	27
Location	27
Surface Area	27
Shape	28
Depth	28
Bottom	28
Dikes	28
Inlet Structure	29
Overflow Structure	29
Multiple Ponds	29
Fencing and Signs	29
Primary Treatment	30
AERATED LAGOONS	30
PUBLIC HEALTH CONSIDERATION	31
ECONOMICS	31
SUMMARY	32

4. THE ACTIVATED SLUDGE PROCESS

PRINCIPLE	1
THE AERATION TANK	3
Diffused Aeration	3
Surface Aeration	3
SECONDARY CLARIFICATION	6
FACTORS AFFECTING THE ACTIVATED SLUDGE PROCESS	6
VARIATIONS OF THE CONVENTIONAL ACTIVATED SLUDGE PROCESS	8
EXTENDED AERATION	9
CONTACT STABILIZATION	9
BARDENPHO PROCESS	12
PROCESS CONTROL TESTS	13

5. PREVENTIVE MAINTENANCE

GENERAL	1
SUMMARY	7
APPENDIX	8
Maintenance Frequency Metering Guide . . .	11
Industrial and Electronic Control	16
Electrical Motor and Generator	19
Auxiliary Engineers and Associated Equipment	25
Mechanical Equipment	30
Pumping Stations	33

6. DIGESTION OF SLUDGE

PRIMARY PURPOSE	1
THE ANAEROBIC DIGESTION PROCESS	1
CRITICAL FACTORS IN SLUDGE DIGESTION	4
Quality of Sludge and Digester Sizing	4
Quality of Sludge	8
Temperature	8
Mixing	9
Gas Production	12
ANAEROBIC DIGESTER START-UP	12
SINGLE STAGE DIGESTION OPERATION	14
General	14
Loading	14
Process Criteria	15
Supernatant Selection	17
Digested Sludge Removal	17
TWO STAGE DIGESTION	18
General	18
Loading	18
Process Criteria	19
Sludge Transfer	20
Supernatant Selection	20
Digested Sludge Removal	22
THE AEROBIC DIGESTION PROCESS	22
General	22
CRITICAL FACTORS IN PROCESS	23
Air Supply	23
Volume of System	23
Tank Insulation	24
OPERATION AEROBIC DIGESTER SYSTEM	24
System Start-Up	24
Sludge Feed	25
Supernatant Control	25
Transfer Program	25
Processed Sludge Removal	26
Air Control	26
Scum Control	26
Records	26

7. **SLUDGE HANDLING**

GENERAL	1
CONSIDERATIONS IN SLUDGE HANDLING	1
Sludge Concentration	1
Sludge Quantities	2
Sludge Withdrawal	4
Example 1	5
CONDITIONING OF SLUDGES	7
Use of Chemicals	7
Wet Air Oxidation	8
DEWATERING	9
Drying Beds	11
Vacuum Filtration	13
Centrifuging	16
Sludge Lagoons	16
Heat Drying	17
FINAL DISPOSAL	18
Incineration	18
Land Disposal by Liquid Haulage	18
Sludge Composting	20

8. **CHLORINATION OF SEWAGE**

PURPOSE	1
CHLORINE PROPERTIES	2
SUMMARY	2
Physiological Effects	3
REACTION OF CHLORINE IN SEWAGE	3
CONTROL OF CHLORINATION	5
Chlorine Dosage	6
OTHER USES OF CHLORINE	6
Odour Control	8
Aid to Sedimentation	8
BOD Removal	9
Grease Removal	9
Activated Sludge Process Control	9
Sludge Thickening	10
Breakdown of Concrete and Mortar	11

8. CHLORINATION OF SEWAGE Cont'd...

TESTING FOR CHLORINE RESIDUAL	11
D.P.D. Test	11
Amperometric Titration Test	11

9. SAMPLING AND RECORD KEEPING

SAMPLING	1
Purpose	1
TYPES OF SAMPLES	1
Grab Sample	1
Composite Sample	2
TYPES OF SAMPLING DEVICES	3
Automatic	3
Manual	4
COLLECTION OF SAMPLES	4
SAFETY SAMPLING	4
WHERE TO SAMPLE AND TYPE OF SAMPLE REQUIRED . .	5
Raw Sewage, Primary Effluent, Plant Effluent	5
Raw Sludge	6
Anaerobic Digested Sludge - Primary Digestion	6
Anaerobic Digested Sludge - Secondary Digestion	6
Digester Supernatant	6
Aeration Tank	6
Aerobic Digester	6

9. SAMPLING AND RECORD KEEPING Cont'd

LABORATORY TESTS	7
General	7
Settleable Solids	7
Mixed Liquor Suspended Solids	8
Sludge Volume Index	8
Total Solids and Volatile Solids Test	9
Dissolved Oxygen	9
Volatile Acids	10
Chlorine Residuals	10
Ministry Laboratory Tests	10
RECORDS	11
SOLIDS BALANCE	16
CONCLUSIONS	18

10. SAFETY PRACTICES IN TREATMENT PLANTS

INTRODUCTION	1
HAZARDS	1
BODY INFECTION	2
PHYSICAL INJURIES	3
HAZARDOUS MATERIALS	3
THE PLANT SAFETY PROGRAM	4
Injury Records	4
Locating the Hazards	5
Equipment, Plant Arrangements, Working Methods	5
Some Protective Safety Equipment	5
GENERAL PLANT SAFETY	6
Building Maintenance	7
Hand Tools	8
Portable and Power Tools	8
Tools and Machines	8
Welding	8
Inspections of Tools and Equipment	9
Ladders	9
Lifting	9

10. SAFETY PRACTICES IN TREATMENT PLANTS Cont'd

Sanitation	9
Storerooms	9
Working Area	10
Trucks and Equipment	10
Barricades and Traffic Control	10
EQUIPMENT SERVICING	11
PRECAUTIONS FOR ELECTRICAL MAINTENANCE	12
FIRE PROTECTION	14
CHEMICAL HANDLING AND STORAGE	15
LABORATORY	16
SAFETY PRACTICES IN WORK AREAS	17
No Smoking	17
Hazardous Gases and Fuels	18
Influent Building	18
Grit Removal Area	19
Primary and Secondary Settling Tanks	19
Pump Rooms	19
Aeration Tanks	20
Digesters	20
Chlorine Buildings	21
Wet Wells	21
Dry Wells	22

11. SETTLING TEST

GENERAL	1
APPARATUS	1
PROCEDURE	2
SLUDGE VOLUME INDEX (SVI)	3
Example	3
Calculations	3
SLUDGE DENSITY INDEX (SDI)	4

12. DO ANALYSIS

METHODS OF ANALYSIS	1
DO METERS	1
General	1
Calibration of the DO Meter and Probe	2
ZERO CHECKING THE DO PROBE	4
CALIBRATION - LABORATORY PROCEDURE	5
Alternative Procedure for Calibration	5
CHEMICAL METHODS	8
DO Sample Preservation of Mixed Liquor Samples	8
WINKLER METHOD	10
Apparatus Required	10
Procedure	11
Calculation	12
THE HACH DO KIT	13
Procedure Using the Hach DO Kit	13
PREPARATION OF REAGENTS	15
Copper Sulphate - Sulphamic Acid	15
Manganous Sulphate Solution	15
Alkaline Iodide - Azide Solution	16
Sulphuric Acid	16
Starch "Solution"	17
Sodium Thiosulphate Solution (0.025N)	17
Potassium Dichromat Solution (0.025N)	18

13. CHLORINE TESTING PROCEDURES

DPD METHOD	1
Principle of the Method	1
Equipment and Reagents Required	1
Procedure - Total Chlorine Residual	2
AMPEROMETRIC TITRATION METHOD	3
General	3
Titrator - Principle of Operation	3
Procedure	4

SUBJECT: 1

TOPIC: 1

WASTEWATER TREATMENT OPERATION

**INTRODUCTION
TO SEWAGE
TREATMENT**

OBJECTIVES:

The trainee will be able to:

1. Describe, using a diagram, the typical sewage treatment plant.
2. Identify three sources of municipal sewage.
3. Discuss in general terms the physical, chemical and bacteriological characteristics of sewage.
4. Recall the approximate percent BOD and suspended solids normally removed in:
 - a) the primary treatment plant,
 - b) the secondary treatment plant.
5. Define terms commonly used in sewage treatment operations.
6. Explain the importance of nutrients in the operation of sewer treatment plants.
7. Discuss the effects of inadequately treated plant effluent on receiving waters.

WASTEWATER CHARACTERISTICS

GENERAL

The treatment of wastewater is one of the most important responsibilities of municipalities.

In the 19th Century, several large European cities built closed conduits or pipes for collecting human wastes when the use of streets as open sewers created intolerable living conditions. The discharge of these wastes to nearby watercourses soon produced obnoxious odours and unsightly conditions.

During the same time period, epidemics were increasingly being traced to water supplies originating from the polluted watercourses. It was then discovered that bacteria contained in the sewage caused diseases such as Typhoid Fever, Dysentery, and Cholera. The treatment of wastewater thus became a necessity.

Sewage is a specific term used to describe toilet wastes present in the flows of collection systems. Wastewater is a term used to define the total liquid contents of collection systems. Often key words are used before the term wastewater to better distinguish its source, ie: municipal, commercial, industrial. Wastewater contains vast numbers of living organisms, most of them too small to be visible without the aid of a microscope. They are a natural living part of the organic matter found in wastewater and they are important because they are one of the reasons for the success of our present treatment processes. The microscopic living organisms in sewage include bacteria, algae, protozoa, viruses, fungi and other higher life forms.

Intensive study of the microorganisms has indicated that few of them cause disease. These microorganisms are often destroyed in nature by the metabolic activities of higher forms of microbial life. Together, the organisms play a major role in degrading or breaking down organic matter. The degradation of organic matter can best be accomplished by encouraging the growth of micro-organisms in a controlled biological reaction that intensifies the natural process. The intensified method is referred to as the Activated Sludge Process.

SOURCES

In nature, sewage is present as the waste by-product of human and animal life. Man has added to this the waste products of industrial and commercial activity. So the composition of wastewater varies widely in both quantity and quality.

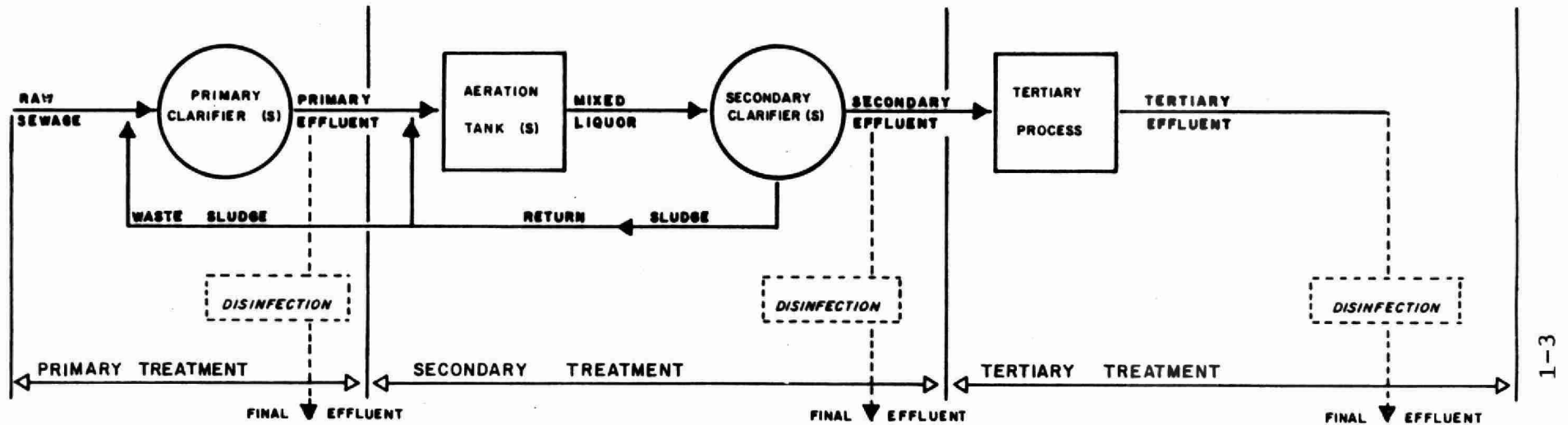
Domestic wastes are those that originate in the bathroom, kitchen and laundry room. Once they reach the collection system and combine with any industrial and/or commercial wastes, they are collectively referred to as wastewater. Wastewater is easily treated in a properly designed wastewater treatment facility. Industrial and commercial wastes contained in the wastewater may sometimes be unacceptable for treatment in a municipal wastewater facility. In these cases, the wastes must be pre-tested before they are discharged into the collection system.

Figure 1-1 is a schematic diagram of a typical wastewater treatment facility. Primary treatment is a physical/chemical stage used to remove settleable solids from the wastewater flowing through the primary clarifiers. The liquid leaving these tanks, called primary effluent, may then be disinfected and discharged to a watercourse or discharged to a watercourse or directed to a secondary stage for biological treatment. The organic matter in the primary effluent serves as food for large numbers of microorganisms (activated sludge). This stage can occur in tankage called aeration tanks or on a medium especially designed and constructed from rock or plastic. With adequate oxygen, the organisms use the food for energy and reproduction.

The contents of the aeration tanks, called mixed liquor, then flow into clarifiers where the organisms are allowed to settle and a clear liquid (secondary effluent) is either disinfected then discharged, or directed to a tertiary treatment process. The settled activated sludge is returned to the aeration tank for reuse. An over production of activated sludge must be eliminated from this cycle and is wasted away to any of the sludge handling processes.

FIGURE № 1-1

TYPICAL SEWAGE TREATMENT PLANT



1-3

REMOVAL OF B.O.D. & S.S.	B. O. D.		SUSPENDED SOLIDS (S.S.)	
	% Removed	Effluent mg/l	% Removed	Effluent mg/l
PRIMARY PLANT	30 - 40	90 - 150	40 - 60	100 - 150
SECONDARY PLANT	95	15	90 - 95	15
TERTIARY PLANT	98	5	98	5

Tertiary treatment can further remove solids and organic matter, using physical, chemical, or biological treatment unit processes.

Before being discharged to any watercourse, the plant effluent may be disinfected by chlorination, or ultraviolet radiation other disinfectants to destroy any remaining pathogenic (disease-causing) organisms.

The liquid leaving the plant is called final effluent. Chemicals may be added to the wastewater at any point of treatment to increase removal efficiencies or to control the individual unit processes.

QUANTITY

In addition to carrying domestic, industrial and commercial wastes, the collection systems may receive large quantities of water through broken and poorly constructed sewer pipes and direct storm drain connections (illegal and crossed connections). This is called infiltration. Older collection systems may collect sanitary wastewater and storm water in a single pipe, however the separate collection of each is essential, since a treatment facility must be designed according to the total flows reaching it. It would be uneconomical to construct a large facility to treat immense quantities of very dilute wastewater which only arrive during rainy periods.

The total quantity of wastewater reaching a facility is called the hydraulic load, varying from hour to hour and day to day. Normally, daily flows will range between 70 and 130 percent of the community's water consumption. This percentage will rise if infiltration of ground and surface water is a major factor. Flows will lessen due to lawn watering, car washing, hydrant flushing and other domestic and industrial uses from which the used water is not discharged to the sanitary sewer system. An average community without large industrial wastewater contributors will produce approximately 450 litres of wastewater per capita per day. Small rural communities will produce approximately 225 litres per capita per day. Solids account for less than 0.1 percent by weight of the total wastewater flow. The other 99.9 percent is water, functions as a carrier to move the solids through the pipes.

QUALITY

A treatment facility removes undesirable materials from the wastewater, making it acceptable for discharge to receiving water courses. In so doing, the biological, physical, and chemical characteristics of the wastewater are changed. These changes can best be seen by comparing the characteristics of the plant influent, primary effluent, secondary effluent, and final effluent of a treatment plant.

Bacteriological Characteristics

Fresh influent may normally contain from 10 to 200 million bacteria per 100 millilitres. Some are harmful to humans and others are not. Complete secondary treatment reduces these numbers by 80 to 95 percent, with effluent disinfection increasing the percentage "kill" to 99.9 percent or better. The highest reductions are generally achieved only when the treatment plant is operating efficiently.

Physical Characteristics

The physical characteristics of wastewater are temperature, turbidity, colour and odour. Table 1-1 compares the physical changes which take place through typical treatment.

TABLE No. 1-1

FLOW	TEMPERATURE	TURBIDITY	COLOUR	ODOUR
Plant Influent	generally warm	high in solids	milky-grey to black	musty to sulphurous
Primary Effluent	lower temperature	fine nonsettle-able solids	greyish to colourless	musty to sulphurous
Secondary Effluent	lower temperature	no visible solids	clear colourless	fresh

The influent temperature can vary, depending on the source of water supply for the community. However, the resultant influent is generally somewhat warmer than the water supply. As the sewage passes through the facility, the temperature decreases. Higher influent temperatures, result in faster decomposition and better settleability.

Influent is highly turbid, containing different types of solids such as paper, rags, garbage, feces, sand and silt.

Primary effluent contains finely suspended and some floating matter that is reduced by the biological unit process, to produce a clear, colourless secondary effluent.

The influent's usual milky-grey colour will not be evident if coloured industrial wastes or partially decomposed (septic) waste-waters are involved. Septic wastewater is dark, often black in colour with a sulphurous odour. Normal sewage smells musty but not unpleasant. Primary effluent is similar to influent except that the settleable solids are removed. The secondary effluent of a properly operated biological treatment plant is clear and colourless, with a fresh odour. Effluent disinfection does not affect temperature, turbidity, or colour. A fresh chlorine odour is evident if chlorine is the disinfectant applied to the treated wastewater.

Chemical Characteristics

Chemically, wastewater is composed of inorganic and organic solids that are carried in water. The wastewater can contain dissolved gases and living organisms. Inorganic substances are inert and generally will not decay or burn. Organic materials will decompose and are sometimes called volatile matter since they will burn when heated to high temperature.

Solids

Inorganic and organic substances that can be seen in the wastewater are known as suspended solids. These are the solids which are removed from the wastewater by physical or mechanical means, such as sedimentation. Invisible (to the eye) solids are classified as dissolved solids. Total solids, include all the solids contained in the wastewater.

Inorganic solids consist of sand, silt, clay, the dissolved minerals and salts of community water supplies and any other inert matter contained in wastes discharged to sewers. Hard water produces a higher mineral content in the wastewater. The more common minerals and salts found in wastewater are sulphates, carbonates, bicarbonates and chlorides of calcium, magnesium, sodium, potassium and iron. These are beneficial to the microorganisms and not normally troublesome wastewater treatment. Organic solids are generally of animal or vegetable origin. Some synthetic compounds, are also organic in nature. Organic matter consists of hydrogen, oxygen and carbon and can be combined with inorganic nitrogen, sulphur or phosphorus. The principle groups formed are called proteins, carbohydrates and fats. These serve as food for bacteria and other organisms, resulting in decomposition of the organic matter. Decomposition results in the formation of carbon dioxide (CO_2), nitrogenous compounds of ammonia, (NH_3) nitrites (NO_2), and nitrates (NO_3), and sulphurous compounds such as hydrogen sulphide gas (H_2S), various sulphate compounds. The cycles of life, death and decay involve carbon, nitrogen and sulphur. These elements recycle in our environment and the by-products of decay become food for plant and animal life.

The concentrations of solids, whether inorganic or organic, change continuously and vary in each treatment facility. Typical concentrations of solids in medium strength wastewater are shown graphically in Figure 1-2. Wastewater strength is related to the amount of organic material present in it. Successful operation of biological treatment process, upon this wastewater strength because the wastes provide food for the organisms.

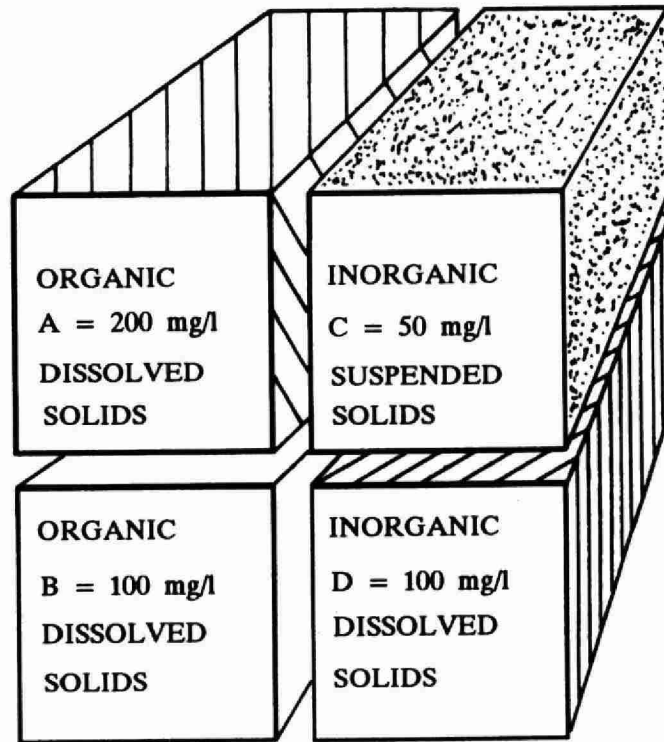
Total solids in wastewater consist of all suspended and dissolved inorganic and organic materials. From Figure 1-2 it can be seen that the concentration of total solids in medium strength wastewater is approximately 450 mg/L. This consists of 300 mg/L organic matter and to 150 mg/L of inorganic matter. The same total solids figure is arrived at by adding the values for suspended and dissolved solids (shown as 250 mg/L and 200 mg/L respectively).

When storm or ground water finds its way into the system, the relationships of these solids changes significantly. Similarly, industrial and commercial wastes can increase the solids content with definite variations in the strength of the wastewater. Also, wastewater will vary widely in both composition and volume from hour to hour, depending upon changes in community activities.

Wastewater is likely to be at its maximum strength and flow during the daytime and at its minimum during the night hours. On weekends and holidays, flows and strengths are often reduced due to lessened communal activity. Therefore, remember that wastewater data on sewage can never be applied equally to all wastewaters at all times.

Primary treatment will normally reduce suspended solids by 40 to 60%. Complete secondary treatment generally will remove 90 to 95% of the suspended solids, producing a final effluent with suspended solids less than 15 mg/L.

Figure 1.2
Composition of Solids in a Medium Strength Raw Sewage



TOTAL SOLIDS = $A+B+C+D = 200+100+50+100 = 450$ mg/l

TOTAL ORGANIC SOLIDS = $A+B = 200+100 = 300$ mg/l

TOTAL INORGANIC SOLIDS = $C+D = 50+100$ mg/l

TOTAL SUSPENDED SOLIDS = $A+C = 200+50 = 250$ mg/l

TOTAL DISSOLVED SOLIDS = $B+D = 100+100 = 200$ mg/l

Biochemical Oxygen Demand (BOD)

The standard for determining the organic strength of wastewater is the Biochemical Oxygen Demand (BOD). This is a measure of the oxygen used by the micro-organisms in decomposing organic matter. The laboratory test is conducted at a temperature of 20°C for a period of five days with the result being expressed as mg/L BOD₅ (BOD).

Facility influents will normally have a BOD₅ ranging between 150 mg/L and 250 mg/L. Industrial and commercial wastes can affect this. Primary treatment plant will normally reduce BOD by 40-60%. Complete secondary treatment generally removes 95% of the BOD, producing a final effluent with a BOD less than 15 mg/L.

Dissolved Gases

Wastewater contains varying concentrations of dissolved gases. The most important of these is Oxygen, present in the original water supply and also dissolved in from air in contact with the surface of flow. Sewage may contain other gases, carbon dioxide, ammonia and hydrogen sulphide for example (the products of decomposition). Nitrogen is also present being dissolved in from the atmosphere. These gases can indicate the degree of sewage decomposition.

Nutrients

Nitrogen and phosphorus are two important nutrients of the biological process and also have an effect on the receiving watercourse. Within the biological process they are essential to the growth of organisms involved in the decomposition of organic matter. Municipal wastewater normally contains an excess of both nitrogen and phosphorus. This excess, when discharged in the plant effluent, acts as an undesirable fertilizer, promoting the growth of algae in receiving waters.

Nitrogen is present in wastes in the form of ammonia, nitrite, nitrate, and organic nitrogen, each representing a different stage of waste decomposition.

Total phosphorus is composed of a number of organic and inorganic compounds which may be present in a soluble or insoluble form. These compounds can be grouped into three categories, namely: orthophosphorous, organic phosphorus and polyphosphorus.

Table 1-2 summarizes the ranges of typical nitrogen and phosphorus values for a conventional secondary treatment plant.

TABLE No. 1-2

FLOW	NITROGEN				PHOSPHORUS	
	Ammonia mg/L	Organic mg/L	Nitrite mg/L	Nitrate mg/L	Total mg/L	Soluble mg/L
Plant Effluent	15-50	25-85	less than 0.1	less than 0.5	6-12	4-6
Primary	15-50	25-85	less than 0.1	less than 0.5	4-8	4-6
Secondary Effluent	0-1	5-20	less than 5.0	greater than 10	3-6	2-5

In conventional treatment very little nitrogen and phosphorus are removed, although they may change form chemically. Where high phosphorus removals were noted at activated sludge plants, the influent usually contained aluminum or iron from industrial sources. By adding aluminum, iron or calcium compounds at the treatment plant, total phosphorus can be reduced to less than 1.0 mg/L in the final effluent.

EFFECTS OF WASTE DISCHARGES

When certain wastes, including domestic wastewater, do not receive adequate treatment, large amounts of solids may accumulate on the banks of the receiving waters, or they may settle to the bottom to form sludge deposits or float to the surface and form rafts of scum. This accumulation results in oxygen depletion and also is the source of odours. Primary treatment units in wastewater treatment plants are designed and operated to remove the sludge and scum before they reach the receiving waters: to prevent as much of this "oxygen-demanding" organic material as possible from entering the receiving water.

Although most streams and other surface waters contain less than 10 mg/L of dissolved oxygen most fish can thrive if 5 mg/L litre and other stream conditions are favourable. However, when organic waste is discharged to a stream, bacteria begin to feed on it and decompose or break down the complex substances in the waste into simple chemical compounds. In this process, the bacteria use dissolved oxygen from the water. Where waste flows are high, the population of bacteria may grow large enough to use the entire supply of oxygen from the streams faster than it can be replenished by natural diffusion from the atmosphere. When this happens, fish and most other living things in the stream which require dissolved oxygen will die.

Another effect of oxygen depletion, is the problem of odours. When all the dissolved oxygen has been depleted, then anaerobic bacteria begin to use the oxygen which is combined chemically with other elements in the form of chemical compounds, such as sulphate. When anaerobic bacteria remove the oxygen from sulphate compounds, hydrogen sulphide gas is released which has a rotten egg odour. This gas also erodes concrete and can discolour and remove paint from structures and nearby buildings. Hydrogen sulphide is toxic and can form explosive mixtures with air. It is capable of paralysing the respiratory system and deadening the sense of smell.

Some wastes can adversely affect the clarity and colour of receiving waters making them unsightly and unpopular for recreation.

Many industrial wastes are acidic or basic and pH can interfere with aquatic life water usage. Prior to discharge treated effluents should have a pH similar to that of the receiving water and preferably as near the neutral range as possible (pH7). Industrial waste discharges can contain toxic substances, such as heavy metals or cyanide, that will affect the use of the receiving water. Also, odour producing substances can reach levels in the receiving water which are readily detectable in drinking water or in fish flesh.

Conventional wastewater treatment plants do not remove a major portion of nitrogen and phosphorus nutrients therefore discharges from such plants contain nutrients capable of encouraging excess algae and plant growth in the receiving waters. These growths hamper domestic, industrial, and recreational uses. Therefore, wastewater treatment facilities located on certain water courses require installation of phosphorus removal equipment.

Human Health

The physical and chemical effects that wastewater discharges have on water use are significant. More importantly, however, is the effect on human health through the spread of disease-producing organisms (pathogens). Serious outbreaks of communicable disease have been traced directly to contamination of drinking water, or food supplies by human body wastes. Although the numbers of pathogenic organisms are reduced by natural die-off during the treatment process, sufficient numbers remain to cause a threat to downstream users. Disinfection is necessary when downstream users consume or contact treated effluents.

Disinfection of a well-treated effluents usually result in a reduction to a safe level of these pathogenic organisms. An operator must realize that break-down or malfunctioning of disinfection equipment will result in the discharge of an effluent that contains pathogenic organisms and hence, pose a risk to downstream users.

SUBJECT:

BASIC WASTEWATER TREATMENT

TOPIC: 2

BACTERIOLOGY

OBJECTIVES:

The trainee will be able to:

1. Recall and explain the two main objectives of the wastewater treatment
2. Describe, in general terms, the reproduction of bacteria as it relates to wastewater treatment
3. Explain the metabolic activities of bacteria and the functions of:
 - a. extracellular enzymes
 - b. intracellular enzymes
4. Identify the four main factors affecting bacteria and the effects on bacterial growth
5. Outline the results of bacterial activity and the factors affecting it in:
 - a. the aeration section
 - b. anaerobic digestion
 - c. aerobic digestion
6. Explain the way in which water-borne diseases are spread
7. List four pathogenic diseases found in wastewater

BACTERIOLOGY

WASTEWATER TREATMENT OBJECTIVES

Wastewater is composed of water, organic and inorganic material and living organisms, the largest group of these being the bacteria. Bacteria originate from bathroom, kitchen laundry wastes and some industrial discharges (food processing). Bacteria are present in most wastes, but the vast majority found in wastewater originate from faecal material. Wastes are collected and combined in collection systems and together form wastewater, which eventually enters the treatment plant. Emphasis is on the establishment of large regional collection systems where the pooled wastewater from several communities is treated at one large plant.

The main wastewater treatment objectives are:

1. To Remove Organic Material

The treatment process prevents pollution by transforming dissolved and suspended organic materials into:

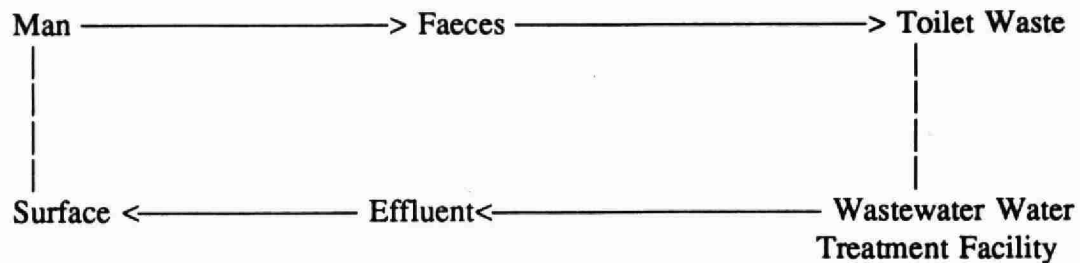
- a. stable mineral compounds
- b. biological cell contents and carbon dioxide and water

Bacteria are the principle agents active in these processes.

If these organic materials were discharged directly to a receiving water, the process of breakdown would still occur, but the oxygen present in the water would be used up, algae would grow on the partial breakdown products and the visible signs of "pollution" would appear, such as slimes, smells and dead fish.

2. To Eliminate Disease Producing Agents (Pathogens)

Some human diseases such as typhoid, polio and dysentery, which infect the intestinal tract, are transmitted from man to man by faecal discharges. Pathogens are present in the faeces of infected individuals and will eventually be found in the wastewater. The cycle followed by such pathogens can be illustrated.



If wastewater is discharged without treatment then surface waters become contaminated by pathogens. In the past, this cycle, resulted in the transmission of the disease when the contaminated water was consumed by individuals. This played a large part in the spread of intestinal disease; these diseases were known as water-borne diseases.

Modern methods of wastewater treatment and disinfection of plant effluents, destroy disease-causing microorganisms contained within the wastes, preventing gross contamination of surface waters.

During treatment of a wastewater's microbial flora (population of bacteria) changes progressively from a predominantly faecal nature to a near enriched fresh-water system. This effect is due to an enforcement of selective conditions within the plant, which tend to be unfavourable to the growth of faecal bacteria, especially pathogens. The organisms capable of growing at the fastest rate under the controlled conditions survive and multiply and others are eliminated.

BACTERIAL STRUCTURE

The structure of a bacterial cell should be considered in order to understand the function of bacteria in wastewater.

Bacterial cells may be characterized by their size, shape and arrangement.

1. Size

Bacteria are extremely small; the majority measure 0.5-1 μm (micron) in thickness (1 μm = 1/1000 mm) and 1-3 μm in length.

An important consequence of the smallest of bacteria cells is that the ratio of surface area to volume is exceedingly high; this allows for very rapid and efficient transfer of materials from outside the cell into areas within the cell where they are utilized.

2. Shape

Although there are thousands of different species of bacteria, the individual one-celled bacterium exhibits one of the following structural forms:

- a. spherical
- b. rod-shaped
- c. spiral shaped

3. Arrangement

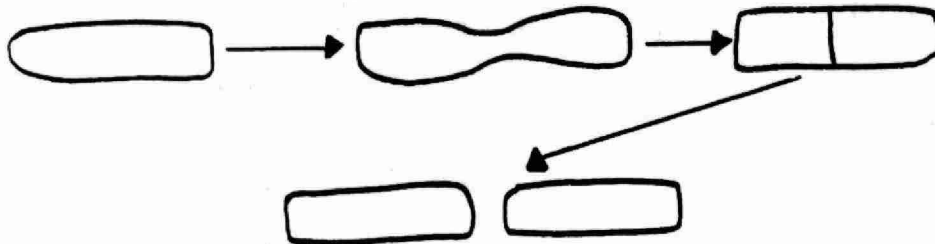
The two structural forms can be observed in the following arrangements:

- a. single cells
- b. pairs of cells
- c. chains of cells
- d. clusters of cells

Each bacterial cell has a cell wall which surrounds a substance known as protoplasm. Food which the bacteria need to grow must pass through the cell wall in order to enter the cell. The protoplasm contains all that is required to sustain cell life, including the numerous enzymes which are produced by the cell.

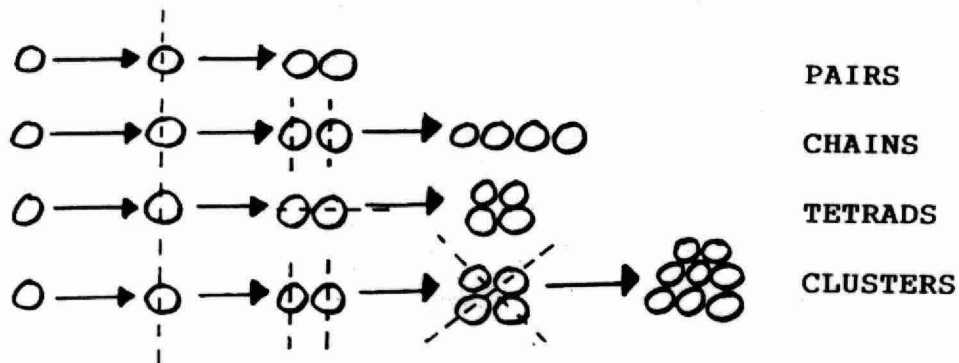
BACTERIAL REPRODUCTION

Reproduction of bacteria is a process whereby one mother cell divides in half, producing two new daughter cells. This process is called multiplication by division (mitosis).



This can result in a very rapid increase in numbers, provided the conditions are favourable, since beginning with a single bacterium, the increase in population is by a geometric progression from 1-2, 2-4, 4-8, 8-16 etc.

The plane in which division takes place determines the arrangement of the resultant cells.



The time interval required for a cell to divide varies with the type of bacterium and the environmental conditions, and can be anywhere from 30 minutes to several days. Reproduction in bacteria is usually halted by:

1. an accumulation of the bacteria's toxic wastes (organic acids etc)
2. exhaustion of the food supply
3. the development of unfavourable environmental conditions

It has been calculated that if bacterial cells continued to multiply at their maximum growth rate, within a year their combined mass would be equal to that of the sun.

METABOLIC ACTIVITIES AND BACTERIAL GROWTH

The metabolism of bacteria may be defined as the way in which their food is used. As a result of these activities:

1. cell material is formed
2. energy for life is obtained
3. waste materials are eliminated

These activities are carried out under the influence of enzymes. An enzyme is an organic catalyst; it is produced by a living cell, and its function is to produce chemical changes in organic and inorganic substances; it is not itself used up in the process. Bacterial enzymes are made up of organic and inorganic substances that increase the speed at which a chemical reaction takes place. Each enzyme is specific to one chemical process only; therefore the bacterium must produce a separate enzyme for each chemical process. It has been estimated that a single bacterial cell contains several hundred different enzymes; these enzymes are capable of performing all the chemical changes associated with life processes. Any impairment of their activity is reflected by some change in the cell, such as a stoppage of growth and/or multiplication, or in extreme cases, death of the cell.

There are two types of bacterial enzymes:

1. **Extracellular Enzymes**

These are excreted through the cell wall, and function outside the cell. Their main task is to break down large organic compounds into small soluble materials so that these can be absorbed through the cell wall into the cell.

2. **Intracellular Enzymes**

These are associated with metabolism inside the cell, utilizing the soluble absorbed materials.

Virtually every organic compound occurring naturally or produced biologically can be utilized as food by some species of bacteria. The ability of various kinds or species of bacteria to utilize specific organic compounds is used to differentiate one species from another eg: some species are capable of fermenting lactose whereas many cannot.

FACTORS AFFECTING GROWTH

Since all growth processes are dependent on chemical reactions brought about by enzymes, and since the rate of these reactions is influenced by physical conditions, it follows that bacterial growth is affected enormously by the physical conditions existing in the environment. The following are the most important:

1. Temperature

The optimum temperature for the growth of most bacteria found in wastewater is 37 degrees C, although they can still survive and grow over a wide range of temperature. Bacterial growth and consequently wastewater treatment will decrease in efficiency as the temperature falls. An increase in temperature, at least as far as the optimum will generally result in increased efficiency.

2. Oxygen

In a treatment process bacteria are usually exposed to oxygen in the dissolved form. Bacteria display a wide variety of responses to free dissolved oxygen:

- a. Aerobic bacteria grow only in the presence of free dissolved oxygen
- b. Anaerobic bacteria grow only in the absence of free dissolved oxygen
- c. Facultative bacteria can grow either in the presence or the absence of free dissolved oxygen. The large majority of bacteria fall into this category.

For optimal activity of aerobic or facultative bacteria, 2-4 mg/L of dissolved oxygen is required, and at least 1 mg/L should be maintained at all times, in a wastewater plant.

3. pH

The pH of the environment is another physical condition affecting the growth of bacteria. For most bacteria, the optimum pH for growth and enzyme function lies between 6.5 and 8.5. A pH of 7 represents neutrality, pH 9 a basic situation and pH 3 an acidic situation.

4. Food Supply

In order for a cell to continue to function, food for energy and cell growth must be available. In the bacterial environment, if too little food is available, growth and reproduction will cease, bacteria will tend to cannibalize each other and will eventually die. If too much food is available, undesirable bacteria may metabolize it faster, creating conditions under which other bacteria cannot survive. Death of all cells as a result of unfavourable conditions may then occur.

BACTERIA AND THE WASTEWATER TREATMENT PROCESS

Removal of Organic Material

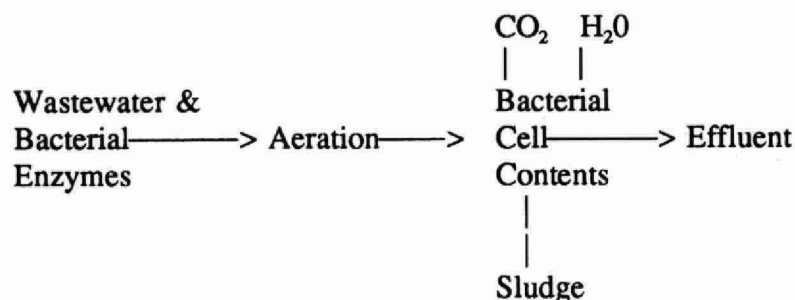
Influent wastewater is generally composed of water, suspended and colloidal solids and other soluble organic and inorganic substances.

Initial sedimentation of solids takes place in a primary clarifier. The unsettled portion of the wastewater enters the biological section of the plant; this could be the activated sludge tanks, or rotating biological contactors depending on the actual plant type. The wastewater is affected to supply the bacteria with tremendous amounts of oxygen. These bacteria metabolize the organic materials by feeding on the wastes contained in the wastewater. Groups of bacterial cells clump together and form a biological floc, that then settles to the bottom of the secondary clarifier as a sludge. Sludge is either recycled to the aerobic process as return activated sludge, or is wasted to a sludge handling unit process.

The aerobic process is subject to seasonal temperature changes; in winter bacterial activity slows down and retention time should be increased to obtain the same effective degree of treatment as the summer time. A decrease in temperature increases the solubility of oxygen, and less air would be required to yield the same dissolved oxygen level. However, the air supply is not normally decreased because the air supply warms the mixed liquor resulting in a increased efficiency.

Essentially, the organic material in the wastewater is converted to bacterial cell material; the cells clump together and settle with organic and inorganic debris and are retained in the plant. A clear effluent relatively free of organic material is then discharged.

The aerobic portion of treatment may be shown diagrammatically as follows:



The Ministry of the Environment does not allow the disposal of unprocessed sludge, except to landfill. Waste sludge from the secondary clarifier plus the solids from the primary clarifier usually is digested. The function of the digester is to further breakdown and stabilize the sludge material, which is made up of the bacterial cells and unmetabolized organic material from the aeration section plus the sludge from the primary clarifier. There are two kinds of digesters, aerobic and anaerobic.

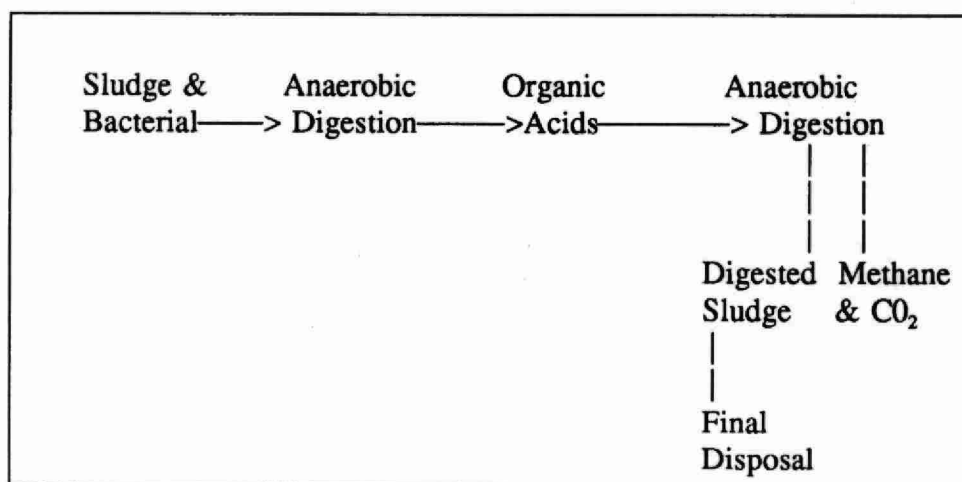
ANAEROBIC DIGESTION

The sludge is pumped into a heated and mixed closed tank. No air is provided and anaerobic bacteria break down the sludge to produce organic acids, such as acetic and propionic acids. A second group of anaerobic bacteria utilize the organic acids and produce methane and carbon dioxide, which is used to heat the incoming sludge. The operation of the digester is sensitive to temperature changes and for optimum activity the temperature should be maintained at 37 degrees C.

Anaerobic digestion is also greatly affected by food supply; if sludge is fed excessively fast, the first group of bacteria form the volatile acids too rapidly and they accumulate. Conditions become acidic and the pH drops to a point where the methane producing bacteria cells will not grow. The digestion process is then incomplete.

The process is also very sensitive to inhibitors; as little as 0.01 mg/L of an inhibitor such as a chlorinated hydrocarbon in the influent wastewater, may be concentrated to 1 mg/L in the sludge, and can inhibit the entire process. If an upset occurs, anaerobic digesters are very difficult to restart, and the contents may have to be landfilled and the whole process restarted with an empty digester.

Anaerobic digestion may be represented diagrammatically as follows:



AEROBIC DIGESTION

This type of digestion is common in small communities and is of value for surplus sludge at larger plants. The sludge is aerated in an open tank. Operation at above ambient temperatures increases the efficiency of the process but is normally not economical; aerobic digesters are however, usually bermed, to retard heat loss. Within the aerobic digester essentially the same processes occur as in the aeration section of the plant. There is a 30% reduction of suspended solids within 20 days. Daily or continuous feeding is better than once or twice per week. If an upset occurs, it can usually be reversed by simply restoring the dissolved oxygen to the tank contents.

The air volume requirements are similar to those of the aeration portion of the plant, and is feasible only in small plants when the cost of the supplied air is not a major portion of the operating expenses. Supernatant from the digester is recycled back to the influent to be treated in the liquid phase of the process.

A disadvantage of aerobic digesters is their tendency to ice up in the winter; floating chunks of ice can damage aeration equipment.

Bacteria often are responsible for the rapid changes in the characteristics of the wastewater. After passage through a treatment plant most of the organic and inorganic matter, both solid and in solution, is removed and a clear effluent is discharged to the receiving stream.

The sludge that remains in the plant, is stabilized after digestion, but still contains nutrients and organic matter of fertilizing value. This sludge can normally be applied to agricultural fields, according to the Ministry's sludge disposal guidelines. Sludges that are not suitable for agricultural disposal are incinerated or transported to landfill.

ELIMINATION OF PATHOGENS

In the past contaminated water has played a large role in the spread of disease. It is a matter of record that when proper water and wastewater treatment facilities have been installed in a community, the health of its inhabitants has improved noticeably and their life span has been extended.

Many bacteria found in wastewater are normal inhabitants of the intestinal tract of man and animals. When an individual is suffering from an intestinal disease, disease-producing bacteria will be excreted in large numbers in the faeces and will enter the wastewater. Because some members of a community will be infected with intestinal diseases at all times, wastewater from that community will always contain pathogenic organisms.

Pathogenic organisms refer to all biological agents capable of causing disease in man. Enteric pathogens refer to a pathogenic group that normally abound in the gastro-intestinal tract. Pathogenic bacteria are not solely responsible for disease in humans. Other pathogenic organisms include algae, viruses, protozoa and fungi.

Some disease organisms precipitate out with the large solids in the primary clarifier, and many more with the sludge from the aeration section. Some destruction of these bacteria occurs as a result of the activity of other microorganisms and many more are destroyed during the digestion process. However, the plant effluent will contain the pathogens that remain in suspension and these must be destroyed before the effluent is released to the receiving stream. For this reason, some form of disinfectant (chlorine, ozone or ultra violet radiation) is usually applied to the effluent before discharge. If the effluent is of good quality and the disinfectant is applied efficiently most of the pathogenic organisms will be destroyed and any remaining will not be in sufficient number to cause a public health hazard in the receiving stream.

Samples for bacteriological analysis are taken as a measure of the efficiency of plant operation and of the disinfection procedure. Total coliforms, faecal coliforms and faecal streptococci are all "normal inhabitants" of the intestinal tract and are present in large numbers in wastewater. If laboratory tests show that total coliforms have been reduced in numbers by 90-99% it can be assumed that all pathogenic forms, which tend to be more readily destroyed by the disinfectants, have been reduced to a non-hazardous level. Faecal coliforms and faecal streptococci are used as similar indicators of efficiency.

Since pathogenic organisms are always present in wastewater, a certain amount of care is essential in the performance of required tasks. It is advisable to wear protective clothing when direct contact with wastewater is unavoidable. The clothing should be laundered or disposed of after being used. Hands and face should be washed thoroughly after any procedure involving contact with wastewater.

SUMMARY

1. Wastewater treatment is a biochemical process and bacteria are the principal agents in the decomposition of organic materials.
2. The bacteria do not act in any special way to accomplish treatment. It is a natural process which has been harnessed and confined within a facility, where optimal conditions for bacterial activity can be controlled and maintained.
3. The mechanism which enables rapid decomposition of wastes at normal temperatures is the bacterial enzyme system. Without bacterial activity, the wastewater treatment process would require the supply of large amounts of energy, eg: burning in a furnace, which would be very costly.

SUBJECT:

TOPIC: 3

BASIC WASTEWATER TREATMENT

PRIMARY TREATMENT

OBJECTIVES:

The trainee will be able to:

1. Recall the purposes of flow records
2. Name five flow control devices used in pumping stations
3. Explain the purposes for installing preliminary treatment devices in sewage treatment
4. Name, describe and explain the functions of the preliminary treatment devices in sewage treatment plants
5. Name three types of grit removal devices and explain their operation
6. Give three reasons for pre-aeration of raw sewage
7. Describe the function of the primary clarifier
8. Describe the operation of a lagoon, using a diagram
9. List four common problems encountered in lagoon operations

PRIMARY TREATMENT

PUMPING STATIONS

Wastewater in the collection system enters the treatment facility by **gravity flow**, by **pumping stations**, or **ejector stations** located in collection system or at the plant site. See Figure 3-1. Wastewater is screened at pumping stations to protect the mechanical equipment in the station. Flows entering a pumping station are recorded. Recording flow enables the operator to assess the flow entering the plant, to verify plant flow recording devices, or to detect infiltration in the collection system. Pumping stations located at critical points in the collection system may be equipped with standby emergency pumping equipment to ensure that service is maintained continuously, even during major power interruptions.

FLOW CONTROL

Flow through a pumping station is controlled by one of the following devices:

1. Manual Operation
2. Float
3. Bubbler (Pneumatic)
4. Electric (Probes)
5. Flowmatcher
6. Pneumatic Ejector
7. Sonic
8. Timers

Manual Operation

It is usually not economical to have an operator at the station at all times; however, all stations should have manual control. It allows the operator some flexibility when visiting the station. By having manual control, the operator can test the operation of the equipment, and, in case of emergencies, can actually control the operation.

Float

Simple, moderate in cost but somewhat troublesome in most raw wastewater applications. The rise and fall of the float actuates mercury-tip switches that start, stop or change the speed of the pumping units.

Bubbler (Pneumatic)

A small air supply causes bubbles to escape from an open-ended pipe submerged in the wet well below the lowest level to be controlled. The pressure of the air in the pipe manifold changes with the submergent depth and actuates pressure sensitive switches that start, stop or control the speed of the pumping units. This system offers distinct advantages over the float system for use in wastewater because the air pressure in the pipe prevents clogging, and there are no moving parts in contact with the liquid. The system is relatively inexpensive, reliable and easily serviced.

Electric (Probes)

This system, usually of the probe type, consists of a pair of insulated electrodes positioned to contact the liquid surface at pre-determined levels. When contact is made the electric circuit is completed, and a signal is relayed to the pumps. If the liquid level is rising, the signal will activate the pumps until the level has dropped to the desired height. At this point, the electric circuit is broken, and the pumps stop until the liquid level once again rises to complete the electric circuit.

An electric system is relatively expensive and generally has a tendency to foul in wastewater applications and requires a more frequent maintenance schedule than other systems previously described.

Flowmatchers

To fully understand the Flowmatcher system, a knowledge of the wound rotor induction motor is required. Basically, the Flowmatcher controls the operation of the wound rotor induction motor.

A Flowmatcher increases or decreases the resistance applied to the rotor of such a motor by altering the level of the electrolyte surrounding the resistance plates within the Flowmatcher unit. The unit can be used in a continuous pumping operation or a start/stop operation.

The start/stop operation is preferred, since at low speeds (50% of normal full speed) wound rotor motors running for long periods exhibit a very poor power factor, will heat up and could cause **spark grooving** on the surface of the slip rings and brushes.

The units are normally used in critical operations and are subject to vigorous preventive and breakdown maintenance programs.

It is recommended that systems using Flowmatchers maintain spare components at all times.

Pneumatic Ejectors

Wastewater flow into a tank causing the air in the tank to escape and be displaced. The air exhaust vent is then closed and a compressed air inlet is opened which forces the wastewater out the discharge pipe. The inlet pipe and the discharge pipe are equipped with check valves to prevent back flow during operation. Compressors are selected, based on the total head and rate of discharge required.

Advantages of this type of system are:

1. Few moving parts in contact with liquid
2. Clog free
3. Completely enclosed
4. The operation of this unit requires simple maintenance

Sonic Transducers

Sonic elements emit a sensing frequency from a transmitter. The audible clicks are fired at the surface of the liquid in the wet well. A reflected sound is picked up by a receiving detector and the signal is processed electronically. The electronic interpretation can determine the level and the volume of liquid contained in the wet well. This signal is then used to start/ stop pumps in the station. These units are simple to operate and maintain, but costly.

PRELIMINARY TREATMENT

Preliminary treatment is practised to enhance the wastewater for actual physical/chemical and biological processing. Wastewater is pretreated in order to remove/reduce or change the incoming characteristics of the wastewater to protect process equipment from possible damage, or disruption. If the preliminary treatment devices do not function as intended, maintenance costs for pump repairs, digester and clarifier clean-outs, etc., will be increased. The following units are usually associated with preliminary treatment:

1. Screens (coarse, bar, mechanical)
2. Shredding devices (comminutors, barminutors, grinders, rotogrators)
3. Grit Removal Units (channel, aerated tanks, detritors, centrifugal separators)
4. Pre-aeration
5. Flow equalization
6. Chemical conditioning

SCREENS

Screens are used to remove materials which may damage equipment, interfere with the process or which are aesthetically undesirable in the effluent. Two basic types available are coarse screens and fine screens.

Coarse Screens

Coarse screens (commonly called **trash rack** or **bar screens** Figure 3-2) generally have bars spaced from 2 - 15 cm. The screens are usually installed at an angle to facilitate manual cleaning, but some units are available that can be mechanically cleaned. Trash racks are normally installed in pumping stations.

Fine Screens

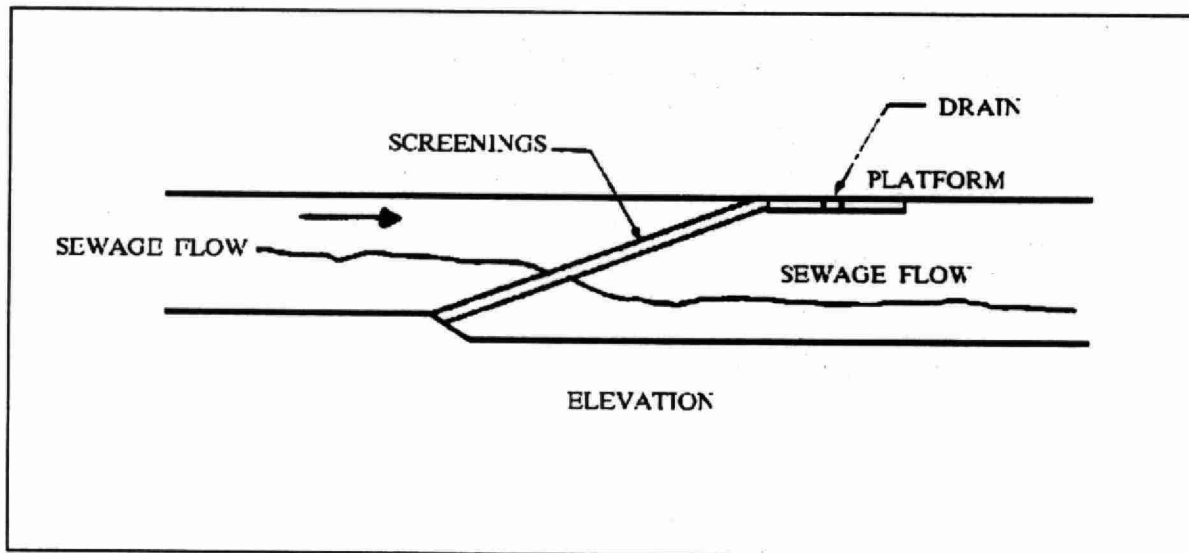
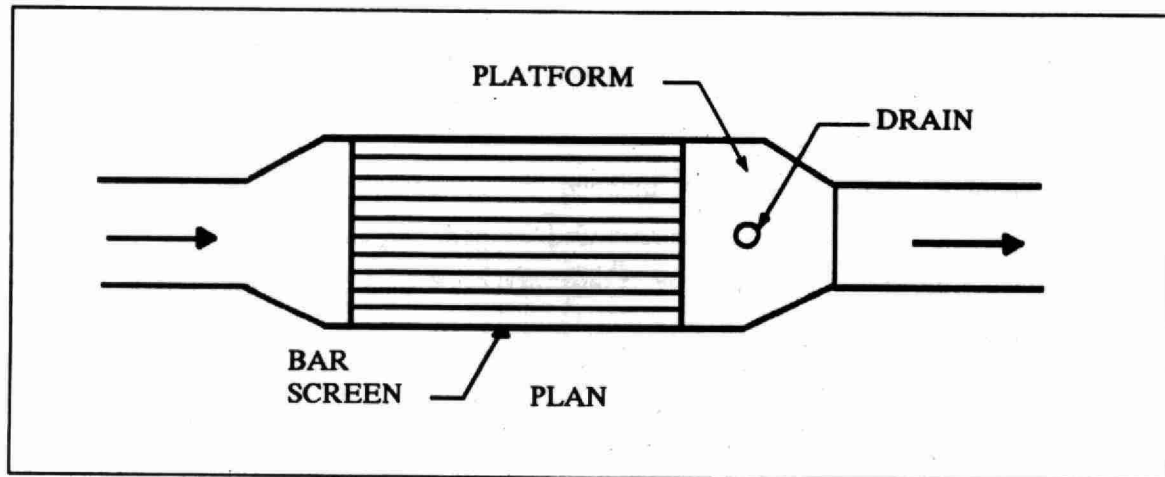
Fine screens were originally used in place of sedimentation tanks. Presently they are not commonly used in sewage treatment because the mesh will accumulate material and plug very quickly, causing what is known as **headloss** in the system; in addition to other operating and economical problems.

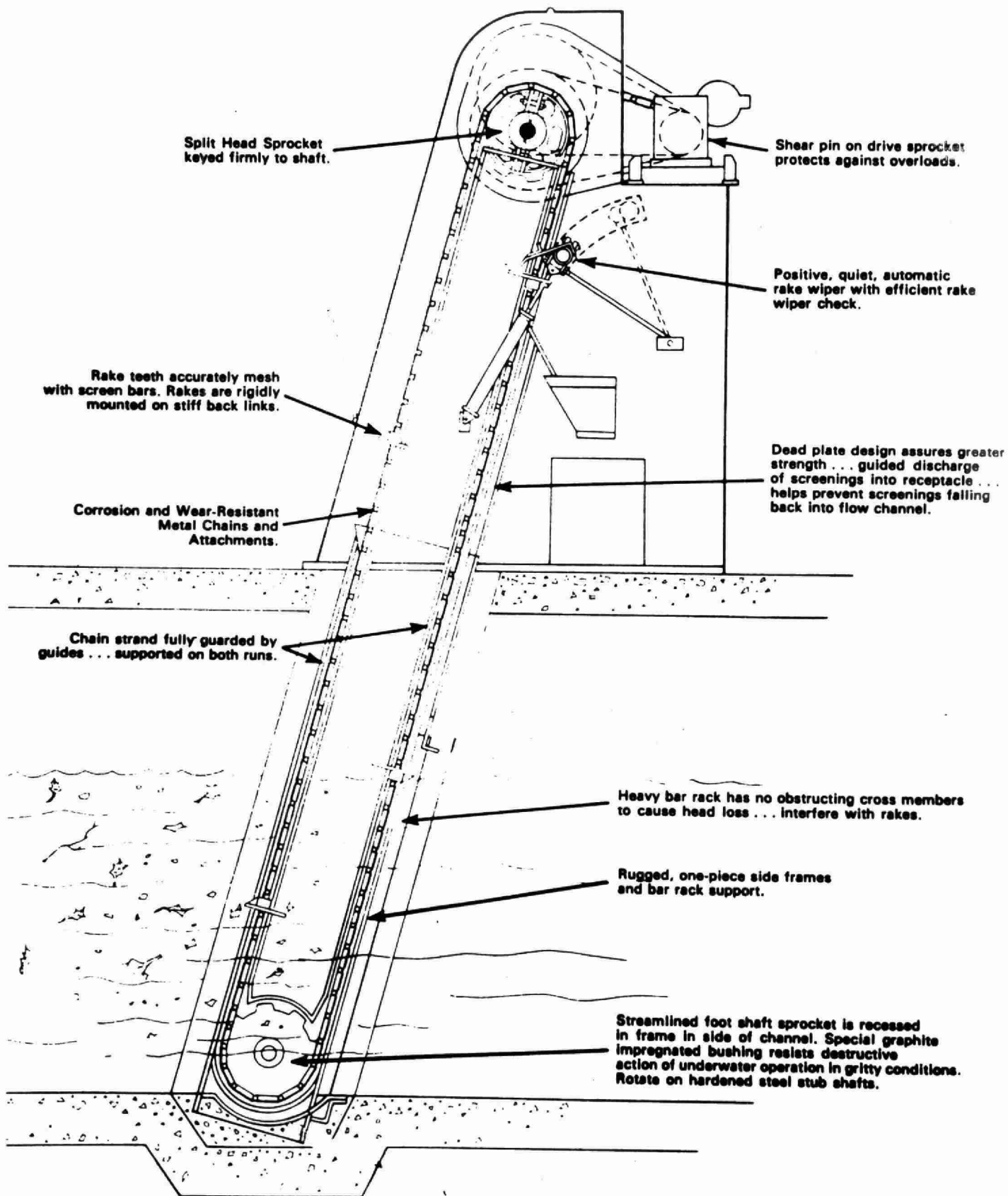
Mechanically Cleaned Screens

Vertical or inclined bar screens are cleaned by a mechanical rake. The accumulated material on the screen is pulled up the screen and "wiped" off into a hopper. Screenings are regularly removed from the hopper to prevent nuisance odours and ensure adequate capacity for incoming screenings. See Figure 3-3.

PRIMARY TREATMENT
BAR SCREEN
HAND RAKED

Figure 3-2





Profile View of a Mechanical Bar Screen

Figure 3-3

(courtesy of REX)

Cleaning Screens

During dry weather periods, **course trash racks** should be cleaned daily. During storm periods, they should be cleaned two to five times per day to maintain a free flow of sewage through the process.

Failure to clean the screens can result in the following:

1. Septic conditions upstream
2. Surcharge of the collection system
3. Shock load on other unit processes when the screens are finally cleaned

Coarse screens, when mechanically cleaned, offer the following advantages:

1. Reduced labour costs
2. Better flow conditions in the process
3. Produce less nuisance

The volume of material or **screenings** removed is difficult to estimate accurately. Generally, a screen with an opening of 3.5 cm will collect approximately 7L of screenings per 1,000 m³ of flow. Figure 3-4 shows the maximum and average quantities of screenings that can be removed.

Disposal of Screenings

The screenings may be disposed of by landfill or incineration. They are the most economical disposal methods. Remove screenings in covered containers. When landfilling screening odour may be prevented by sprinkling powdered lime or other odour control chemicals on the material. An earth cover of one to two feet will usually give the best results for bacterial activity. Grinding devices have been used in the past; the ground screenings are redirected to the influent flow for treatment in the process. This method has proved unsatisfactory however, as it creates digester problems. Screenings received from grinders have caused digester foaming and excessive scum blankets.

Comminutors, Barminutors, or Rotogrators are trade names used by different manufacturers to identify their shredding devices. This piece of equipment is used to shred and grind material small enough to pass through the screens of the unit. Shredders should be installed with a by-pass equipped with a bar screen to facilitate removal of settled material and allow inspection of the equipment components such as the cutting edges.

Shredding devices are normally operated continuously and are usually located ahead of the grit removal units.

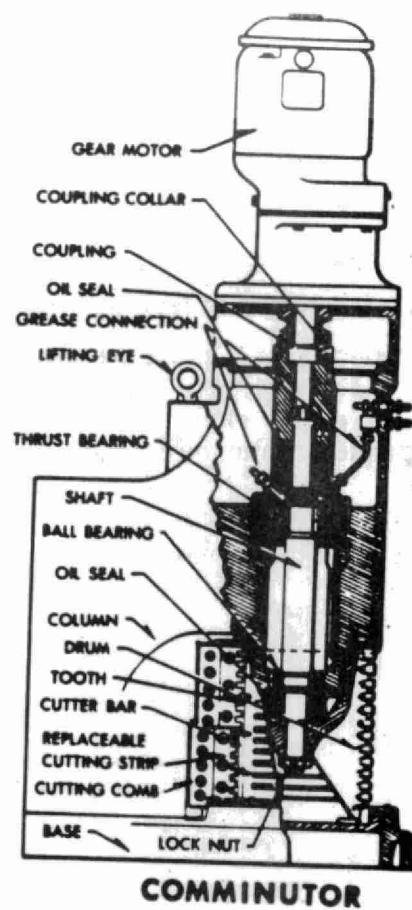
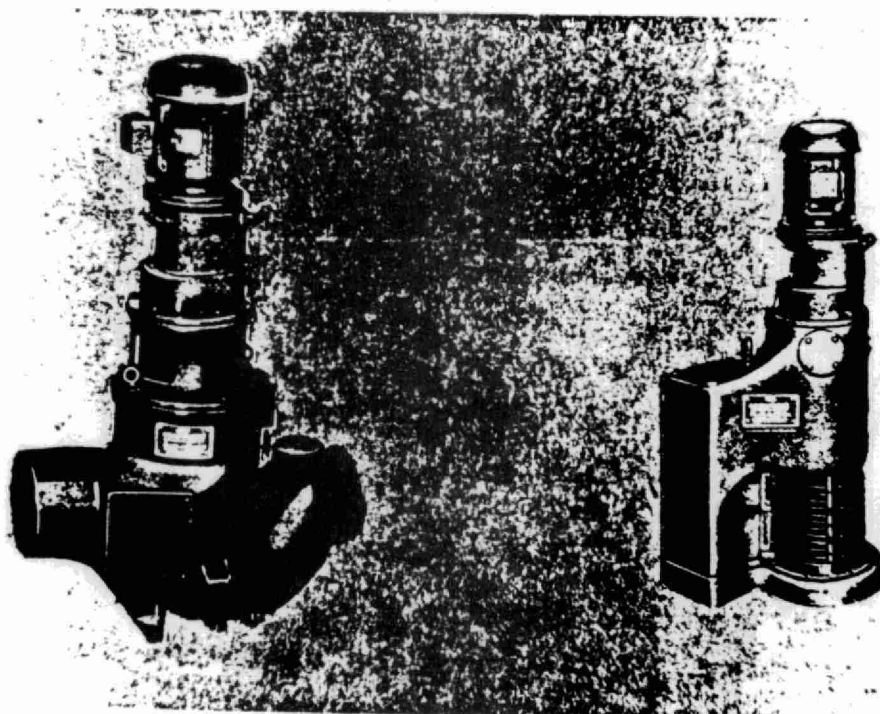


Figure 3-5



Inline Comminutor

Open Channel Comminutor

Figure 3-6

(Courtesy of Smith & Loveless)

GRIT REMOVAL UNITS

Grit such as sand, silt, stones and gravel can find its way into a system and be carried by the flow to the treatment plant.

Grit removal units are installed after screening equipment to protect mechanical equipment from abrasion, avoid pipe clogging, and reduce the sedimentation load on the primary clarifier. Grit removal devices include:

1. grit channels
2. aerated grit chambers
3. detrition
4. centrifugal separators (cyclones)

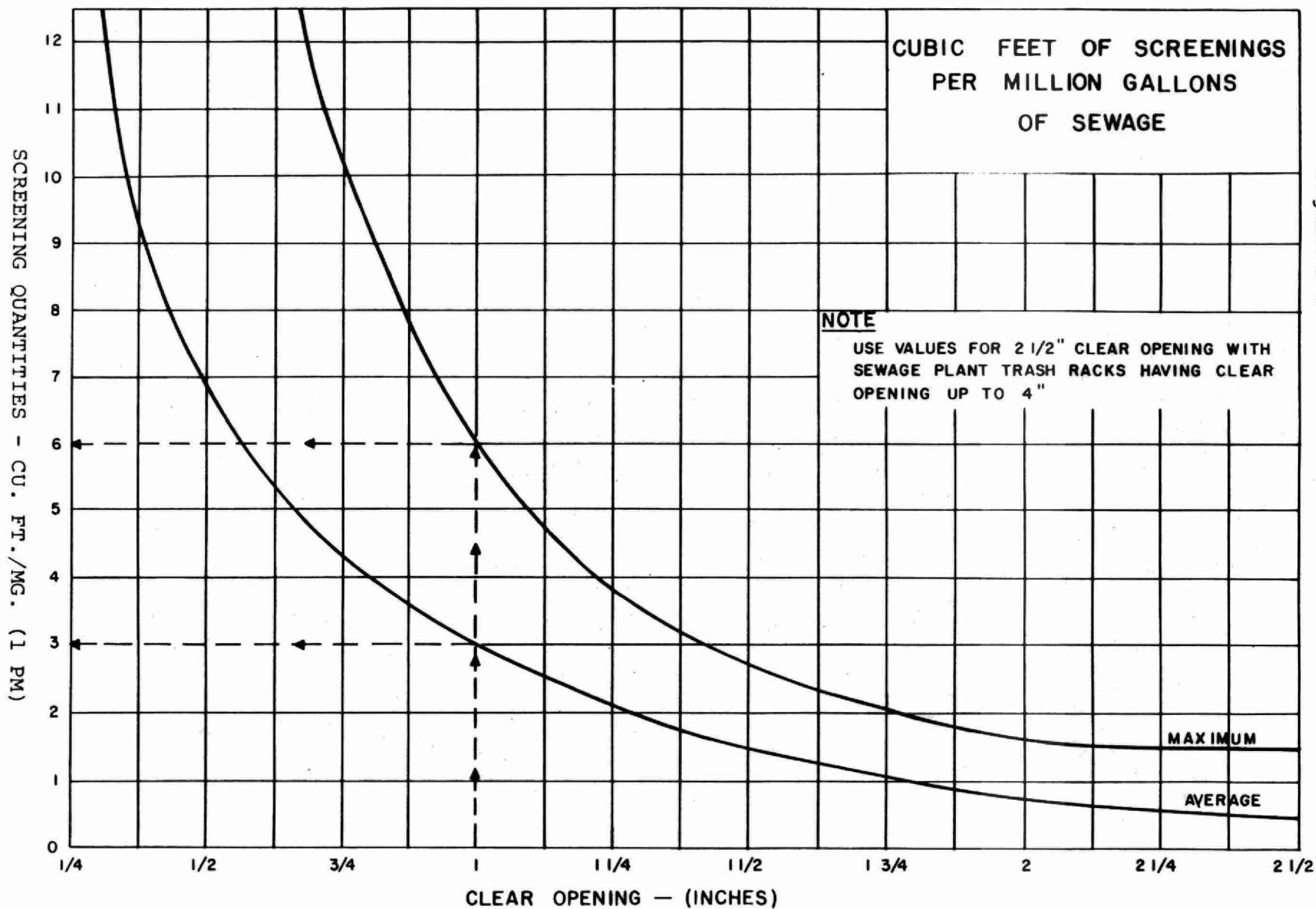
Grit Channels (Figure 3-7)

Grit particles settle faster than organic putrescible solids because they are heavier. Grit channels are designed to maintain a velocity of 0.3 m/s at design flow which is sufficient to keep the organic matter in suspension allowing the heavier particles to settle. Grit channels are rectangular and velocity control is achieved by installing a weir at the effluent end of the channel. Other velocity control devices, can be used.

Aerated Grit Chamber (Figure 3-8)

Grit chambers using air to separate the lighter materials from the heavier ones are called **aerated grit chambers**. Influent flows into the aerated grit chamber and the heavier particles settle to the bottom as the sewage rolls in spiral motion from entrance to exit. The lighter organic particles eventually "roll" out of the tank. The grit at the bottom of the tank is directed to a grit hopper where it is removed by a clam shell bucket or air lift pumps.

Figure 3-4



Detrition (Figure 3-7)

Short-period sedimentation in a tank that operates at substantially constant levels produces a mixture of grit and organic solids called **detritus**. The lighter organic solids are subsequently removed from or washed out of the mixture.

Several manufacturers have perfected this type of equipment. For example, one such unit not only removes the grit but also washes it.

The grit-collecting mechanism is installed in a square, shallow, concrete tank with filled-in sloping corners. Influent enters along one side of the tank through adjustable vertical gates, which are set to provide a uniform influent velocity across the entire width of the unit. Then the wastewater flows straight across the tank and overflows at a weir constructed along the outlet side of the tank.

The collecting mechanism consists of two structural-steel arms, attached to a vertical shaft and fitted with outward raking blades with scoops on the ends. As the rakes revolve, settled grit is ploughed outward to the radius where the end scoops collect and discharge it to a hopper at one side of the tank.

Figure 3-7

GRIT CHAMBER

HAND CLEANED, GRAVITY TYPE

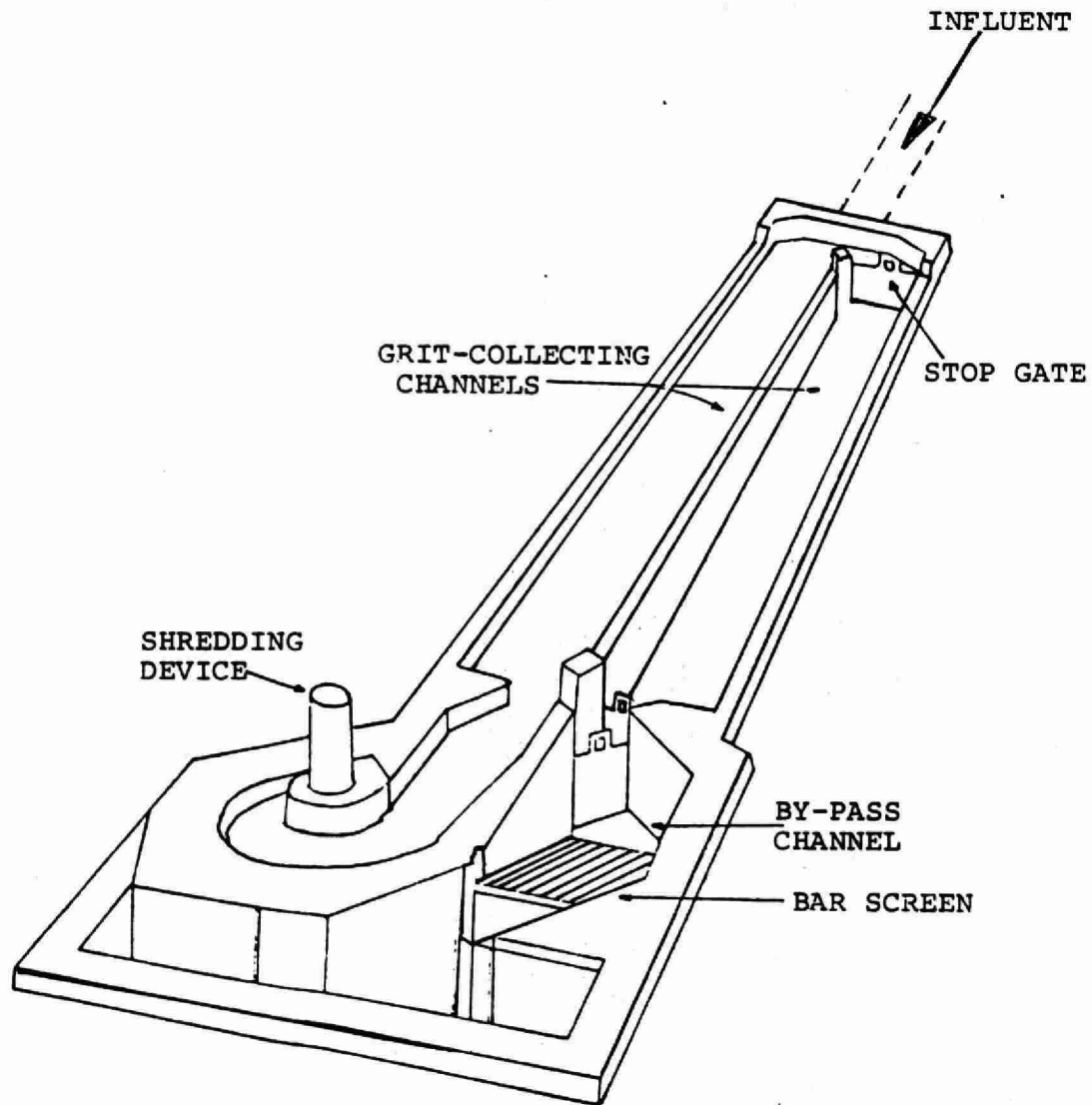


Figure 3-8 Aerated Grit Tank

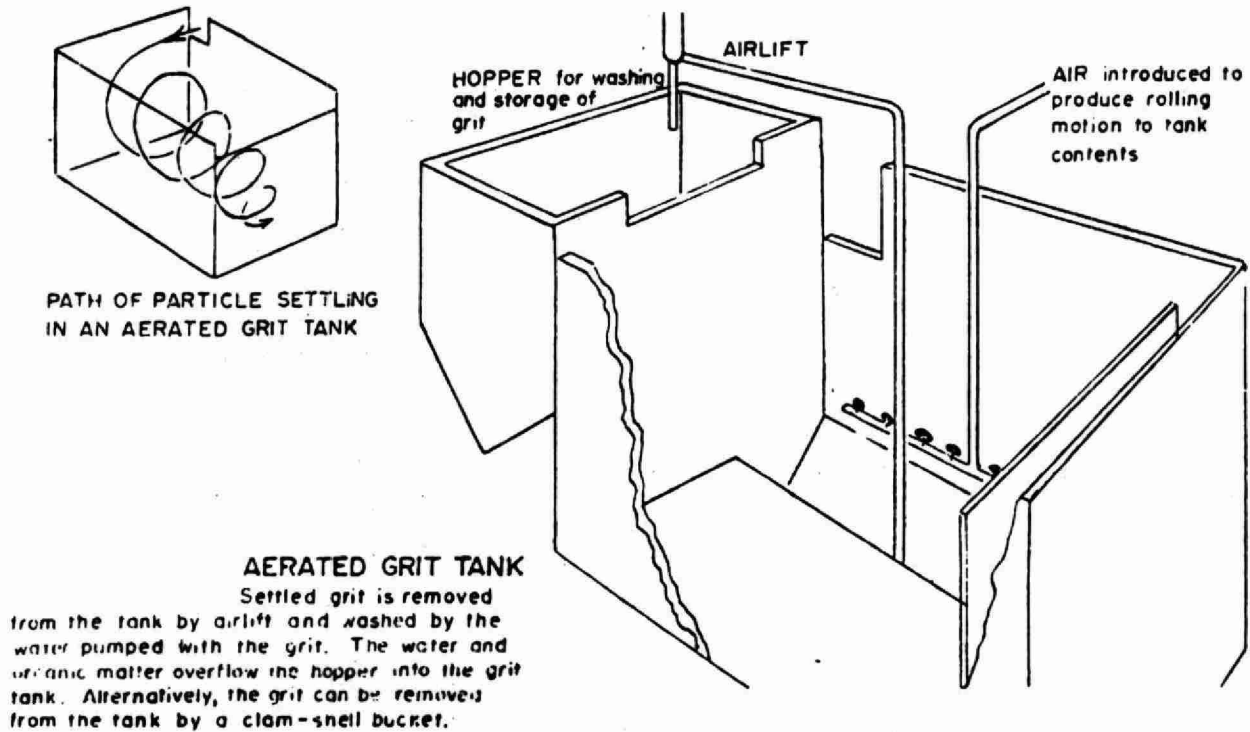
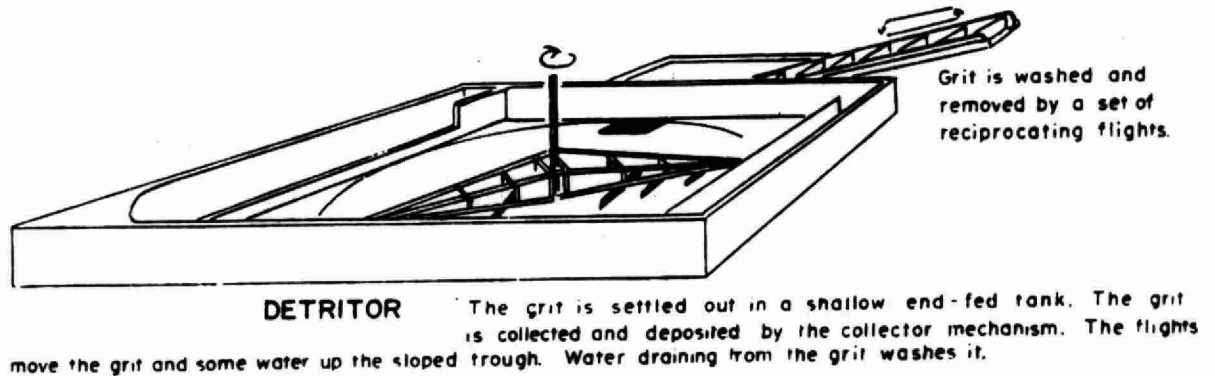


Figure 3-9

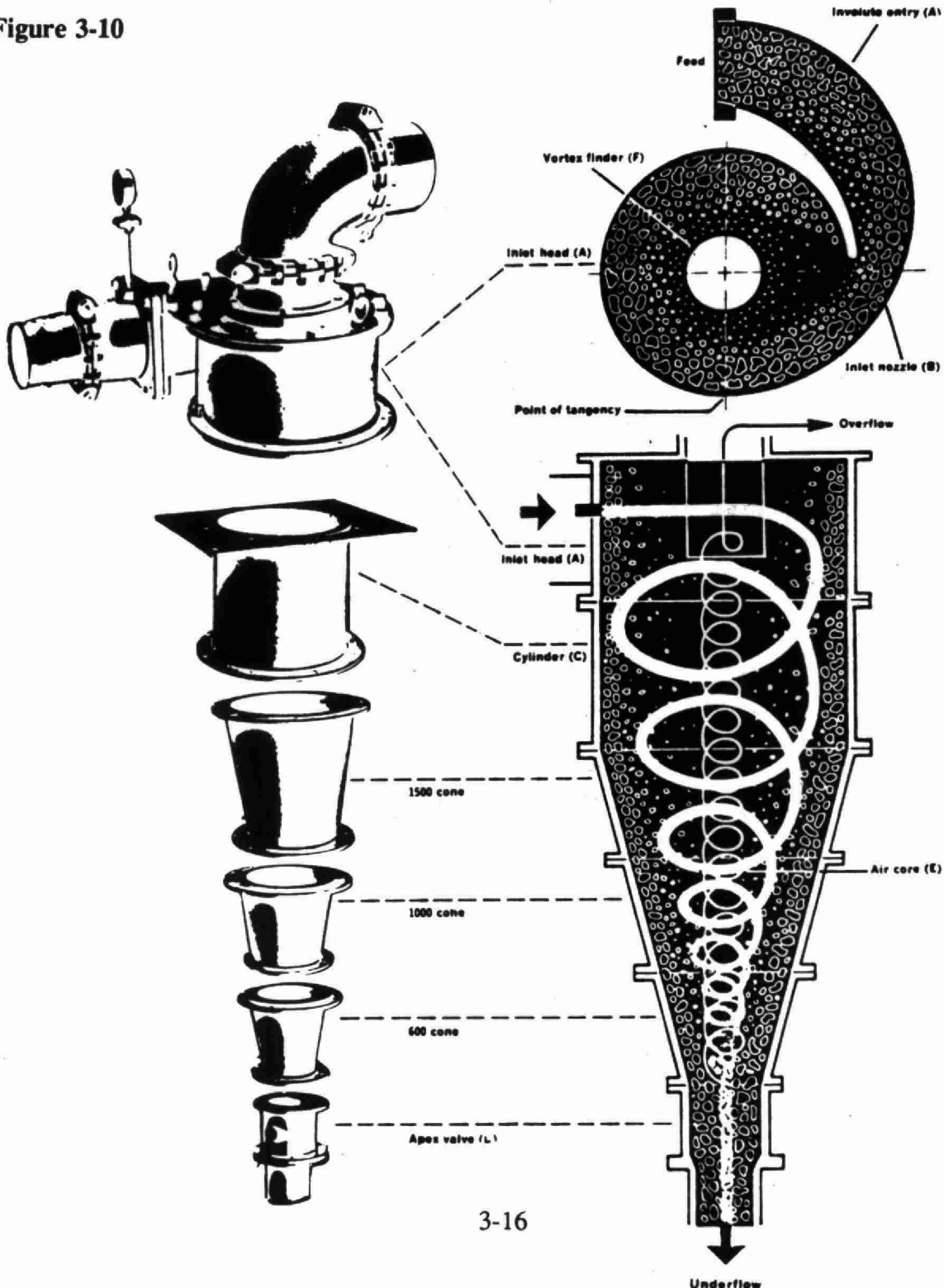


DETRITOR The grit is settled out in a shallow end-fed tank. The grit is collected and deposited by the collector mechanism. The flights move the grit and some water up the sloped trough. Water draining from the grit washes it.

Centrifugal Separators

Grit removal is possible by mechanical means such as a centrifugal unit. Centrifugal units are liquid cyclones. The wastewater is introduced tangentially into a cylindrical conical housing. The heavier larger particles of grit are thrown to the outside wall and collected for disposal. The wastewater leaves the centre of the housing as overflow shown in Figure 3-10.

Figure 3-10



Grit Disposal

Average figures indicate that from 19-50 L of grit can be collected per 1,000 m³ of flow. The grit must be removed before it is carried by the stream flow into the primary clarifier, digester, or chlorine contact chamber. It is good practice to make ensure that the grit is not being carried to the other unit processes, where it would need to be removed with difficulty and expense.

Grit removal can reduce unnecessary maintenance costs more than any other unit process. If these facilities are malfunctioning or improperly operated, the results are plugged lines, abraded impellers, and grit filled tankage.

The disposal of grit is accomplished by landfilling. Grit should be adequately elutriated (washed having less than 3% volatile solids remaining as determined by lab tests) to prevent it from becoming too odourous. The remaining inorganic grit can be used as fill around the plant or be used to re-sand sludge drying beds.

PRE-AERATION

Pre-aeration basins precede primary treatment. Pre-aeration tanks are designed for detention times of 5 to 15 minutes for grease floatation. If flocculation of the fine suspended solids (colloids) in the raw sewage is also attempted, the detention time increases to an upper limit of 60 minutes, the average time being 30 minutes. Approximately 3.75-7.5 m³ of air is required to pre-aerate 1 m³ of wastewater.

Influent is pre-aerated for the following purposes:

1. **To oxidize dissolved gases from the wastewater**, especially hydrogen sulphide, which is toxic to the aerobic process and create odour problems and an increased chlorine demand. The addition of oxygen reduces septic conditions in wastewater. Effective results are achieved with an aeration period of 30 minutes to several hours depending on influent quality.
2. **To promote flotation of excessive grease**, which then can be removed from the wastewater in the primary stage of treatment. Aeration increases the amount of skimmings or grease because the rising air bubbles attach themselves to heavier-than-water particles causing them to float. This buoyancy holds the grease particles in the surface flow. Some demulsifying of the grease occurs which separates it from the sewage. Skimmings are removed by skimming devices, or passed on to the primary clarifier for removal.
3. **To aid in the coagulation of the colloids** (finely divided suspended solids) in the influent for the purpose of obtaining a higher removal of suspended solids by primary clarification.

PRIMARY TREATMENT

Primary treatment devices remove the settleable solids and reduce the suspended solids content of the sewage by 40 to 60%. In so doing, the BOD of the wastewater is also reduced by 30 to 40%.

The following unit processes are considered when discussing primary treatment:
(See Figure 3-11)

1. Clarifiers tanks (Figures 3-12 and 3-13)
2. Floatation processes
3. Sludge handling processes
4. Disinfection processes

The primary clarifier removes, the settleable solids in the wastewater by gravity. The solids collected in the clarifier are referred to as raw sludge. Clarifiers are sized based upon flow and required detention time. The principle of operation is to reduce the velocity of the wastewater as it flows through the tank, allowing the settleable solids enough time to settle out. In so doing, the Biochemical Oxygen Demand (BOD) is reduced by approximately 30 to 40%. Floating solids and scum are also removed in these tanks. Raw sludge solids are directed to solids handling process for further treatment. Effluent water is disinfected before it is released to a receiving stream. Effluent water can be directed to a secondary treatment process if primary treatment alone is insufficient.

Clarifier Operation

Clarifiers come in a variety of shapes: rectangular, square, round, oval and even octagonal. In **rectangular** tanks, the wastewater enters at one end and the effluent overflows the weirs near the opposite end.

Collectors operating in rectangular tanks consist of two end-less chains revolving on sprocket wheels and supporting crossbars, or "flights". The flights push the sludge to a hopper at the end of the tank as they move slowly along the bottom. Flights then move back along the surface to push scum toward a scum trough. The trough extends across the tank and terminates in a pipe which passes through the tank wall. A valve in the pipe is opened before scum is withdrawn. The scum accumulations flow into the trough manually and run through the pipe to a sump for dewatering and then disposal. **Square** tanks can have an inlet on one side with the outlet opposite, or can be centre-fed with effluent weirs along the entire periphery. The sludge collector mechanism rotates about the centre of the tank, scraping the settled sludge into a pit at the centre of the tank and an arm on the surface pushes the grease and scum into a hopper located at the side of the tank.

Circular tanks can be either centre fed or peripherally fed. The sludge collector mechanism is similar to that of the square tank.

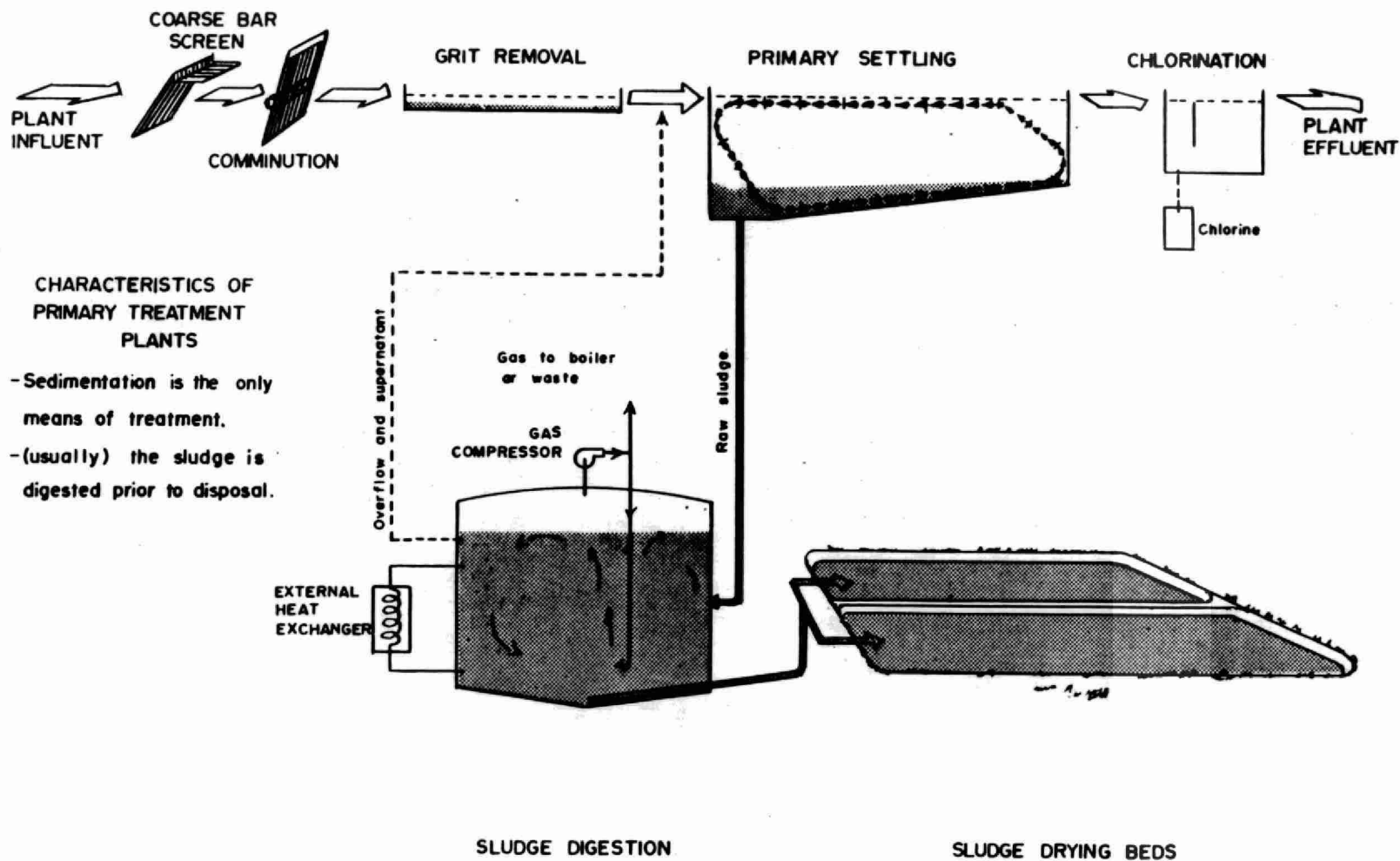
In general, sludge collecting mechanisms in circular tanks are operated over longer periods than collectors in rectangular tanks. Collectors should be run often enough to prevent a build-up of solids in the tank. This will cause an undue load on the mechanism at start-up and subsequently damage the equipment. Solids build-up reduces the tank volume, resulting in a reduced detention time. Also solids may decompose, producing gas and floating sludge. Before sludge is removed from the tank the mechanism should run long enough to assure satisfactory collection of solids in the bottom of the sludge hopper.

Establish and maintain proper time schedules for operation of the mechanical cleaning equipment and for the removal of sludge from the tank. General maintenance should include daily cleaning of all vertical and inclined walls and the removal of all material from baffles and launders algal growths on weirs should be removed periodically.

FIGURE No. 3-11

PRIMARY TREATMENT PLANT

Shown here with a grit channel, rectangular sedimentation tank, single stage anaerobic digester employing gas mixing, and a sludge drying bed.



CHARACTERISTICS OF PRIMARY TREATMENT PLANTS

- Sedimentation is the only means of treatment.
- (usually) the sludge is digested prior to disposal.

Figure 3-12

MECHANICAL SLUDGE COLLECTION
RECTANGULAR TANK

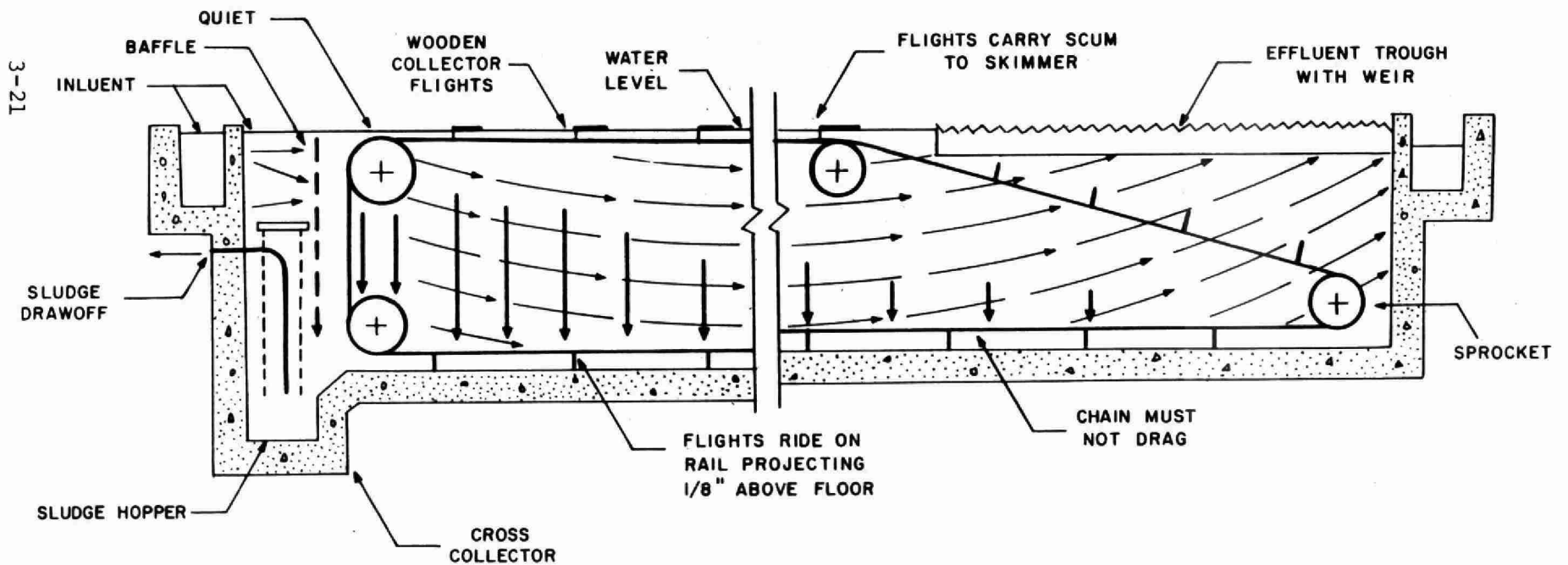
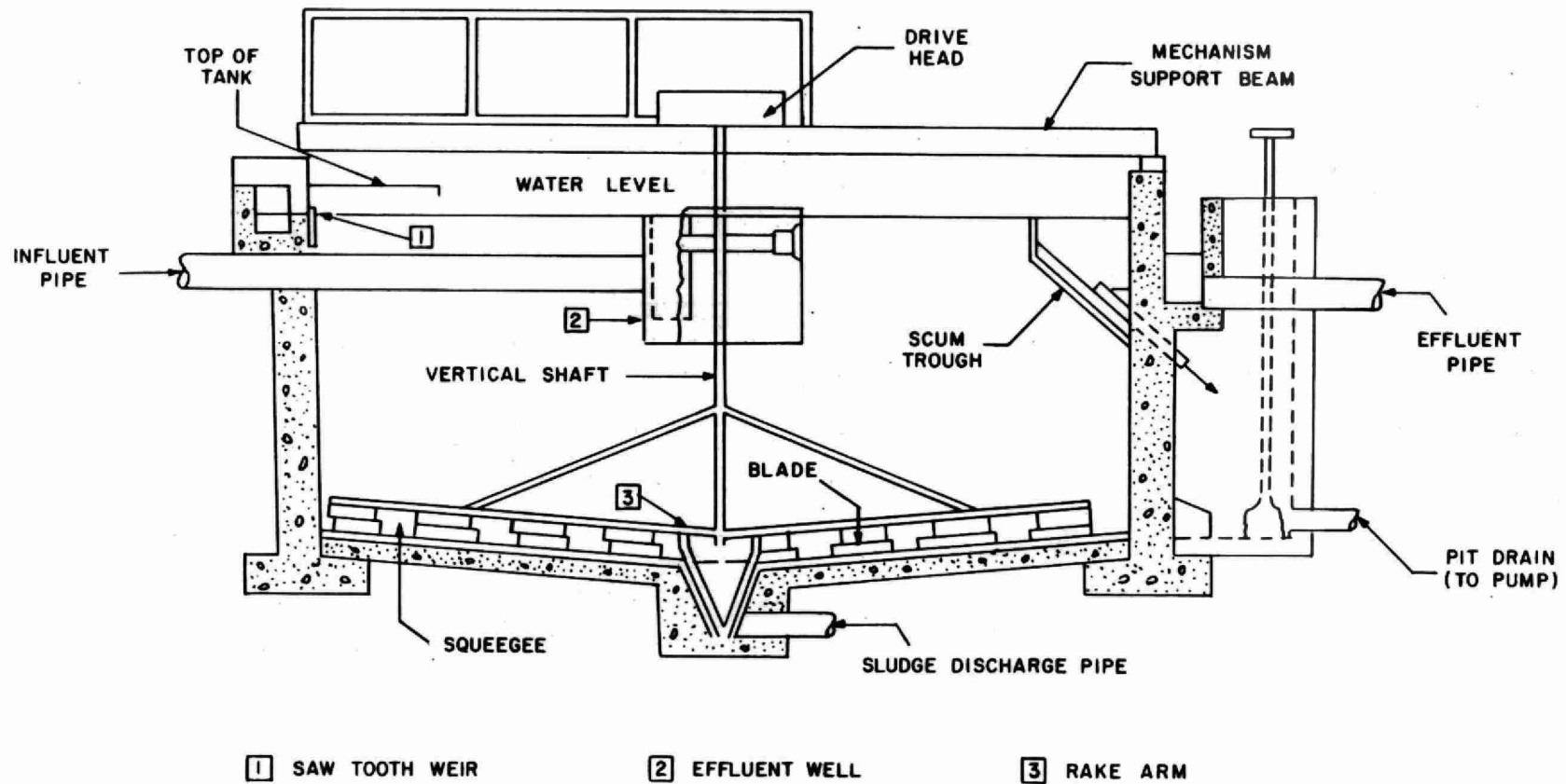


Figure 3-13
CIRCULAR SETTLING TANK
ONE TYPE



Scum Removal

Scum rises to the surface and is pumped out of the hopper for disposal. If scum is pumped to a digester, it should be pumped out of the clarifier first. By doing this, any grease remaining in the pipes will be scoured by the raw sludge when it is pumped. Removal of scum, floating garbage and grease is essential for efficient operation of clarifiers. A scum baffle is generally provided in the flow path between the centre of the tank and effluent weir.

Excessive skimming will result in too much water being carried out with the scum, while insufficient skimming will permit scum to flow around or under the baffle and escape with the tank effluent. Scum must be removed daily, and ideally, small amounts should be removed continually rather than a large batch at one time.

Chemical Precipitation

Chemical precipitation is a modified sedimentation process in which a coagulant is employed to improve the efficiency of settling. Chemicals used include alum, ferric chloride and lime. Proper mixing of these is essential and the dosage will vary according to the characteristics of the wastewater being treated. Efficiencies of 80% to 90% removal of suspended solids and 50% to 55% removal of BOD are common when using chemical precipitation. However, the use of chemicals is an expensive operation and produces a high volume of raw sludge which may be difficult to dispose of, further adding to operating costs.

Flotation Processes

Wastewater always contains some suspended solids that neither settle nor float to the surface and therefore remain in the liquid as it passes through the clarifier. Dissolved solids will travel through the clarifiers because they are unaffected by these units. **COLLOIDS** and **EMULSIONS** are two forms of solids that are very difficult to remove. Colloids are very small, finely divided suspended solids that remain dispersed in liquid for a long time due to their small size and electrical charge. If organic, they exert a high oxygen demand, on biological processes.

An emulsion is a liquid mixture of two or more liquid substances not normally dissolved in one another, but one liquid is held in suspension in the other. They usually contain suspended globules of one or more of the substances. The globules consist of grease, oil, fat, or resinous substances. This material also has a high oxygen demand.

One method for removing emulsions and colloids is by a "flotation process", pumping air into the mixture to cause the suspended material to float to the surface where it can be skimmed off. The particles can be **FLOCCULATED** with air or chemical **COAGULANTS** and carried to the liquid surface by tiny air bubbles. Most of the air bubbles are released at the liquid surface. The resultant scum or foam is removed by skimming.

There are two common flotation processes in practice today:

1. VACUUM FLOTATION.

The wastewater is aerated for a short time in a tank where it becomes saturated with dissolved air. The air supply is then cut off and large air bubbles pass to the surface and into the atmosphere. The wastewater then flows to a vacuum chamber which pulls out dissolved air in the form of tiny air bubbles. The bubbles then float the solids to the surface.

2. PRESSURE FLOTATION.

Air is forced into the wastewater in a pressure chamber where the air becomes dissolved in the liquid. The pressure is then released from the wastewater, and the wastewater is returned to the atmospheric pressure. Because of the change in pressure, the dissolved air is released from solution in the form of tiny air bubbles. These air bubbles rise to the surface and, as they rise, carry solids to the surface.

Flotation processes are based upon release of gas bubbles in the liquid suspension under conditions in which the bubbles and solids will associate with each other to form a mixture with a lower specific gravity than the surrounding liquid. They stay together long enough for the mixture to rise to the surface and be removed by skimming.

WASTE STABILIZATION PONDS (LAGOONS)

A waste stabilization pond is a shallow excavation designed and constructed to receive raw or pre-treated domestic wastewater and some organic industrial wastes. Stabilization is accomplished by several natural purification processes. (See Figures 3-14 and 3-15). The purification process in the lagoon is dependent upon the combined action of wind, sunlight, temperature, sedimentation, bacteria and algae. A portion of the solids in the wastewater settles immediately after the flow enters the pond while the remainder are dispersed by wind action in the overlying water.

The bacteria, which is naturally present in the wastewater and the soil, feed on the organic matter and by digestion convert it into substances which may be discharged into the receiving stream without creating objection or a depletion of oxygen. The abundant supply of soluble nutrients include carbon dioxide, ammonia, nitrogen and other chemical substances released by the bacteria provide an ideal food supply for the algae which grow prolifically near the surface of the pond. The algae are dependent upon sunlight for their activity and release large quantities of oxygen except during periods when the sunlight is excluded. The oxygen in turn is utilized by the bacteria and is in fact absolutely essential to their activity.

Ice cover is a barrier to both light and wind. When snow is present, light penetration is further impaired. Consequently, stabilization ponds become anaerobic soon after ice formation.

Accompanying low temperatures also slows down the bacterial action. At the same time, salts and other sewage constituents become more concentrated under the ice of non-overflowing installations, not only from the continual application of influent, but also by exclusion from ice in the process of freezing. Therefore, melting ice can be expected to provide good quality dilution water in the spring.

Experience of the several states and provinces where lagoons have been used extensively indicate that the degree of treatment provided by waste stabilization ponds is generally equivalent to that provided by conventional activated sludge plants. The reduction in pollution as measured by BOD and suspended solids is commonly in the range of 85 to 95 per cent. Reductions in coliform organisms of more than 99 percent have been reported. No practical method is known today for the disinfection of the lagoon effluent to be discharged into the receiving stream. The high concentration of algae makes disinfection somewhat impractical. It is, therefore, essential that the pond be operated so that no over flow occurs when chlorination of a plant effluent would normally be required to protect the use of the natural waters. In line with the province's guidelines for phosphorus removal for sewage treatment plants located within the compliance area the following program is in effect:

1. Seasonal retention lagoons - this includes those with 180 or 365 day retention - batch treatment with alum or ferric chloride is conducted, achieving even distribution through the use of an outboard motor boat. The phosphorous and algae as well precipitates to the bottom of the cell and the top portion is decanted.
2. Continuous discharge lagoons. In this case a permanent structure is located at a convenient location prior to the lagoon influent so that the chemical may be added to achieve adequate mixing.

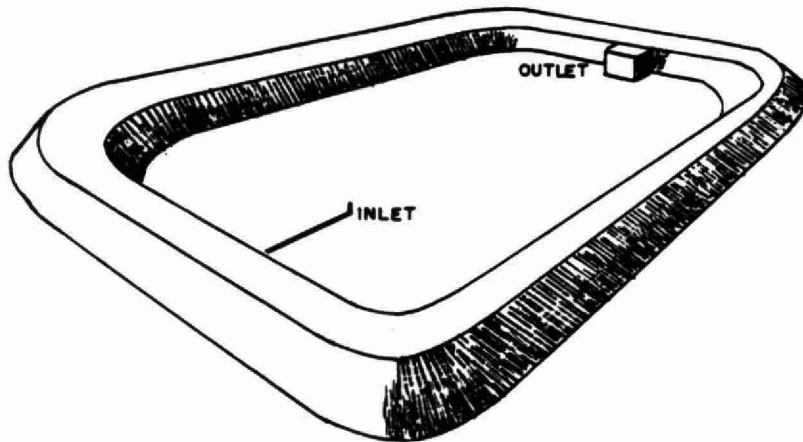


FIGURE 3-14 WASTE STABILIZATION POND The pond has a flat floor and the normal water depth is about five feet.

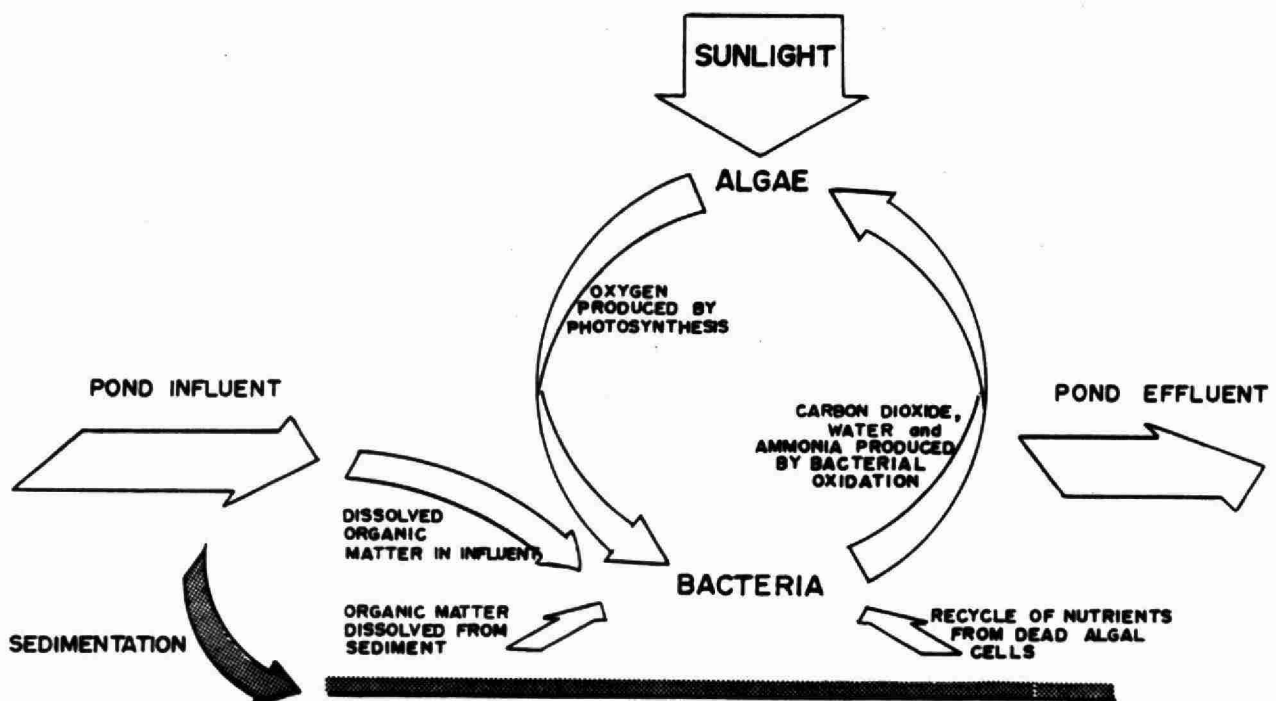


FIGURE 3-15 PROCESSES OCCURRING IN A WASTE STABILIZATION POND including the symbiotic algae - bacteria relationship.

As mentioned previously, cold weather and diminished solar activity in the late fall and early winter reduces the algae and bacterial activity. When the lagoon is ice covered, this activity ceases although some decomposition continues under the ice in the absence of oxygen or under anaerobic conditions. When the ice melts, the gases generated by the anaerobic decomposition process are released to the atmosphere. These gases may become quite offensive, creating odour nuisances in the surrounding area and may persist for periods varying from a few days to several weeks. This is the most critical time of the year in terms of treatment efficiency, difficulty of management and aesthetics.

In some applications, it is necessary to provide storage during the winter months when the lagoon provides a low degree of treatment. This may be accomplished by lowering the water level in the fall of the year when the degree of treatment is high and the streams are in good condition to receive the treated effluent.

DESIGN CRITERIA AND CONSTRUCTION DETAILS

Location

The location of a waste stabilization pond should be based on several factors, namely; cost of land, elevation, prevailing winds, topography, soil characteristics, and proximity and direction of flow in ground water aquifers. The site should be preferably located on the leeward side (downwind) of residential developments in relation to the generally prevailing wind direction and at least 1500 feet from the nearest habitation. In the majority of installations, the elevation of the site has been such that pumping of the flow has been necessary. Soil characteristics should be such so as to produce a minimum percolation into the ground. A seepage rate greater than 5mm/d may require artificial sealing of the lagoon bottom. Gravel and limestone formations should be avoided.

Surface Area

Three basic types of operation should be considered in incorporating area into the design:

1. Total retention (no overflow)
2. Intermittent drawdown (based on receiving stream requirements)
3. Continuous overflow

Fundamental to each type is the maximum loading of the flow and strength equivalent of 250 persons per hectare or 23 kg of BOD per hectare per day. For complete retention, the flow of applied sewage per acre must balance the natural water loss. Considerable data are available on experiences in other states and provinces where higher loadings were utilized with success.

Shape

The overall shape of a waste stabilization pond is not particularly important except as it relates to the surrounding topography. Round, square, or rectangular shapes may be used but care should be taken to ensure that coves, islands or peninsulas are prohibited since they may interfere with circulation and develop local nuisance conditions. Where rectangular shapes are used, the length should not exceed three times the width.

Depth

The optimum depth varies with the season of the year. During the winter season, when the ice thickness may vary from less than 0.25 m to well over 1 m total depth of 1.5 m is desirable. In the early spring, immediately after the ice has been removed, a shallow depth of about 0.75 m would encourage rapid algae growth. In the late spring, summer, and early fall, an intermediate depth of 1 m should produce more uniform temperature conditions. Provision should be made in the design of the overflow device for variable level control between a maximum depth of 1.5 m to a minimum of 0.5 m. At least 1 m of freeboard should be provided.

Bottom

The pond bottom should be graded level for uniformity of water level control. There should be no obstruction to circulation such as raised inlet pipes, debris, or weed growth when the initial application of wastewater is made. Bentonite, asphaltic coating or other suitable material may be used to control the rate of percolation.

Dikes

Compacted embankments of impervious materials should be constructed with a minimum embankment top width of 2.5 m. Maximum embankment slopes should not be steeper than 3 horizontal to 1 vertical for both inner and outer walls. The minimum freeboard should be 1 m plus frost heave. Embankments should be seeded except below the water line. Additional protection for embankments such as rip-rap may be necessary and should be incorporated at the time of initial construction at least along the banks subject to wave action from the prevailing winds.

Inlet Structure

The influent line into single-cell ponds should be essentially centre discharging. Influent lines into the primary section of multiple cell ponds should also be centre discharging but this does not apply to those cells following the primary cell in series operation.

Either upward or horizontal discharging influent lines may be used where the wastewater is pumped to the pond. Horizontal inlets should be used for gravity flow. When upward discharging lines are used, the discharge end of the pipe should be located approximately 30 cm above the bottom of the pond and should not extend to such elevation that ice will damage the terminal structure during winter operation. The end of the discharge line should rest on a suitable concrete apron with a minimum size of 0.4 m². Manholes or cleanouts are recommended where the inlet pipe passes through the embankment.

Influent lines should be placed on or under the bottom. The use of exposed dikes carrying influent lines to the centre of the pond should be prohibited, as such structures will impede circulation.

Overflow Structure

The location of the outlet near the windward shore should prevent any wind induced short circuiting and permit maximum time distance between inlet and outlet. Maximum flexibility in stabilization pond operation may be facilitated by incorporating pond level and effluent draw-off level controls in the overflow. An example of such controls is a stop plank support in a manhole for pond level control and an adjustable level intake structure to the manhole.

Multiple Ponds

The use of multiple cells to provide greater flexibility of operation is desirable. Multiple cells permit both series and parallel operation which offers flexibility in handling fluctuating loads such as are experienced in communities that have a large seasonal influx of tourists. It has also been found that erosion due to wind action has been much less on small two-cell installations than at large single pond construction.

Fencing and Signs

The installation of fencing and "No Trespassing" signs are mandatory. The purpose of the signs is to notify persons of the nature of the facility and discourage trespassing. The minimum requirement for fencing is that it be stock-tight and at least 2 m high to keep out animals and unauthorized persons.

Primary Treatment

Usually, treatment of the wastewater prior to application to the stabilization pond is omitted. Although some savings in land costs may be realized by reducing the BOD loading to the pond by some means of treatment, the initial cost of a primary sedimentation unit plus the operating and maintenance costs usually offset any saving.

Normally, disinfection of the pond effluent is not required. However, disinfection treatment is sometimes provided where protection of the receiving waters is necessary during the recreational months.

AERATED LAGOONS

Since the necessary areas may not always be available for the conventional type lagoons, especially for high BOD loads and flows, it may not always be possible to take advantage of the lagoon type of treatment. As a result, consideration has now been given to the supplying of varying proportions of oxygen to such lagoons by mechanical means.

The use of turbine type mechanical aerators, which disperse and mix compressed air into the liquid mass, permits oxygen absorption efficiencies of a much higher order. The major advantage of the aerated lagoon is the continuous oxygen transfer caused by the turbine aerator. In normal oxidation ponds, the algae produce oxygen only in the daylight hours so that sufficient oxygen must be stored during the daylight hours to satisfy the micro-organisms through the night. The continuous oxygen supply of the mechanical aerator, 24 hours a day, permits the aerated lagoon to handle more wastewater per day per unit volume. Surface aerators can be installed on fixed platforms or on floating rafts which are properly anchored. The agitation provided will prevent freezing in cold climates and also keep the pond aerobic even if a portion of the pond is ice covered. By the use of artificial aerated lagoons, treatment can be practised with only a four to six day retention time. With solids return from a clarifier following the aerated lagoon, total oxidation type treatment could be practised with a one-day retention period. It is also possible to utilize an aerated lagoon in conjunction with a conventional oxidation pond to obtain the benefits of both systems.

Like all waste treatment systems, the aerated lagoon has certain advantages and disadvantages. It appears to have some value where oxidation ponds are overloaded or where property is expensive. The only maintenance required is periodic lubrication of the aerator motor.

PUBLIC HEALTH CONSIDERATIONS

The same precautions that are used in the operation of conventional treatment plants should be practised with waste stabilization ponds. Even though the reduction in bacteria in lagoons is quite high, the possibility of an infection by contact with the wastewater should be recognized. The need for adequate fencing to prevent access by children and animals as well as the posting of signs prohibiting trespassing is warranted.

Ground water supplies, particularly those used for municipal purposes, should not be accessible to the leachate from stabilization ponds. The possibility of disease being transported by wild fowl which frequent these ponds as well as the infection of livestock by watering in streams receiving lagoon effluents should be considered.

Mosquito breeding in lagoons is reduced if weed growths are prevented or eliminated and larvicide is used as required, particularly if difficulty occurs during initial filling.

ECONOMICS

The feasibility of waste stabilization ponds depends largely upon the availability of suitable land. Initially, the development of lagoons may have been retarded somewhat because of the belief that land costs could exceed other financial benefits, such as low operation and maintenance costs and the initial capital cost when compared with other treatment methods. Experience has shown that in many cases the price of land may be about 50 per cent of the cost of the completed waste stabilization pond, yet the total cost has been equal to or less than the cost of a completed secondary treatment plant. In numerous instances, land costs could be double or triple the completed lagoon construction costs before equalling the conventional plant cost.

Experience has also shown that in addition to providing advantages of a high degree of treatment, low initial capital cost and low operation and maintenance cost, the waste stabilization pond is quite flexible in areas that are subject to rapid population growth. It has been found that lagoons may be resited and constructed downstream and the pond area which has appreciated in value may then be reclaimed for housing or industrial site development.

In addition to being an economical method of wastewater treatment, the waste stabilization pond has been useful in polishing primary or secondary treatment plant effluents. These factors do not mean that costs are always less for lagoons. Many details such as longer outfall piping, high pumping costs, high original land costs or difficult construction features may raise costs well above those for the conventional plant. However, a feasibility cost study will indicate the economic advantages of waste stabilization ponds for each installation.

SUMMARY

1. Research and field investigations have definitely proved that waste stabilization ponds are a practical and economical method of treatment.
2. Properly designed and operated stabilization ponds may be expected to provide a degree of treatment comparable to conventional treatment processes.
3. Although stabilization ponds appear to be simple in design and operation, it is essential that the climatic and geographic factors be considered in establishing design criteria.
4. The factors to be considered in site selection for waste stabilization ponds are essentially the same as conventional types of treatment plants.
5. It appears that there are greater potentialities in the propagation of insects and other possible disease vectors than at conventional treatment works.
6. Some of the more common problems are:
 - a) Lagoon inlets and distribution chambers plugging with sand (in collection systems susceptible to sand infiltration).
 - b) Vandalism causing plugged or blocked pipes or distribution chambers.
 - c) Frozen inlet due to excessive lowering of the liquid level in the cell in preparation for winter operation.
 - d) Berm erosion due to wave action in large cells.
 - e) Odours resulting from overloading or toxic materials. Odours are likely to occur when ice breakup and spring turnover occurs.
 - f) Excessive growth of weeds if the liquid level is too low.

SUBJECT:

BASIC WASTEWATER TREATMENT

TOPIC: 4

**THE ACTIVATED
SLUDGE PROCESS**

OBJECTIVES

The trainee will be able to:

1. Describe in general terms the principle of the Activated Sludge Process
2. Name the major components of the Activated Sludge Process
3. List the factors which have a major effect on the Activated Sludge Process
4. Describe using a diagram:
 - a) The Conventional Activated Sludge Process
 - b) Contact Stabilization
 - c) Extended Aeration

THE ACTIVATED SLUDGE PROCESS

PRINCIPLE

After primary treatment, usually by sedimentation or flotation, the treated effluent still contains 60 to 70 per cent of its original organic contaminants. These are in the form of very fine or dissolved organic materials not readily removed by normal mechanical or physical methods. If left untreated, these will cause odours and, eventually, pollution. This material can be broken down biologically by naturally present bacteria in the presence of oxygen by a reduction process known as biochemical oxidation. Since primary effluent contains insufficient bacteria it is augmented by the addition of an activated sludge which is a mixture of small organic solids, living micro-organisms and dead cell contents commonly referred to as **mixed liquor**. It is this solids mass which provides the base to which bacteria cling. These bacteria are known as **aerobic** bacteria.

In the presence of oxygen, the bacteria are able to break down the complex organic substances into simpler organic compounds, which in turn are broken down by different bacteria to nitrates, phosphates, carbon dioxide and water. This is the principle of the activated sludge process.

The activated sludge process is, therefore, an aerobic process and must be supplied with oxygen at all times. Without oxygen, the bacteria will die, the oxidation process will come to a halt and a foul smelling black sludge will develop. In this state, the sludge is said to be **anaerobic** (lacking free oxygen).

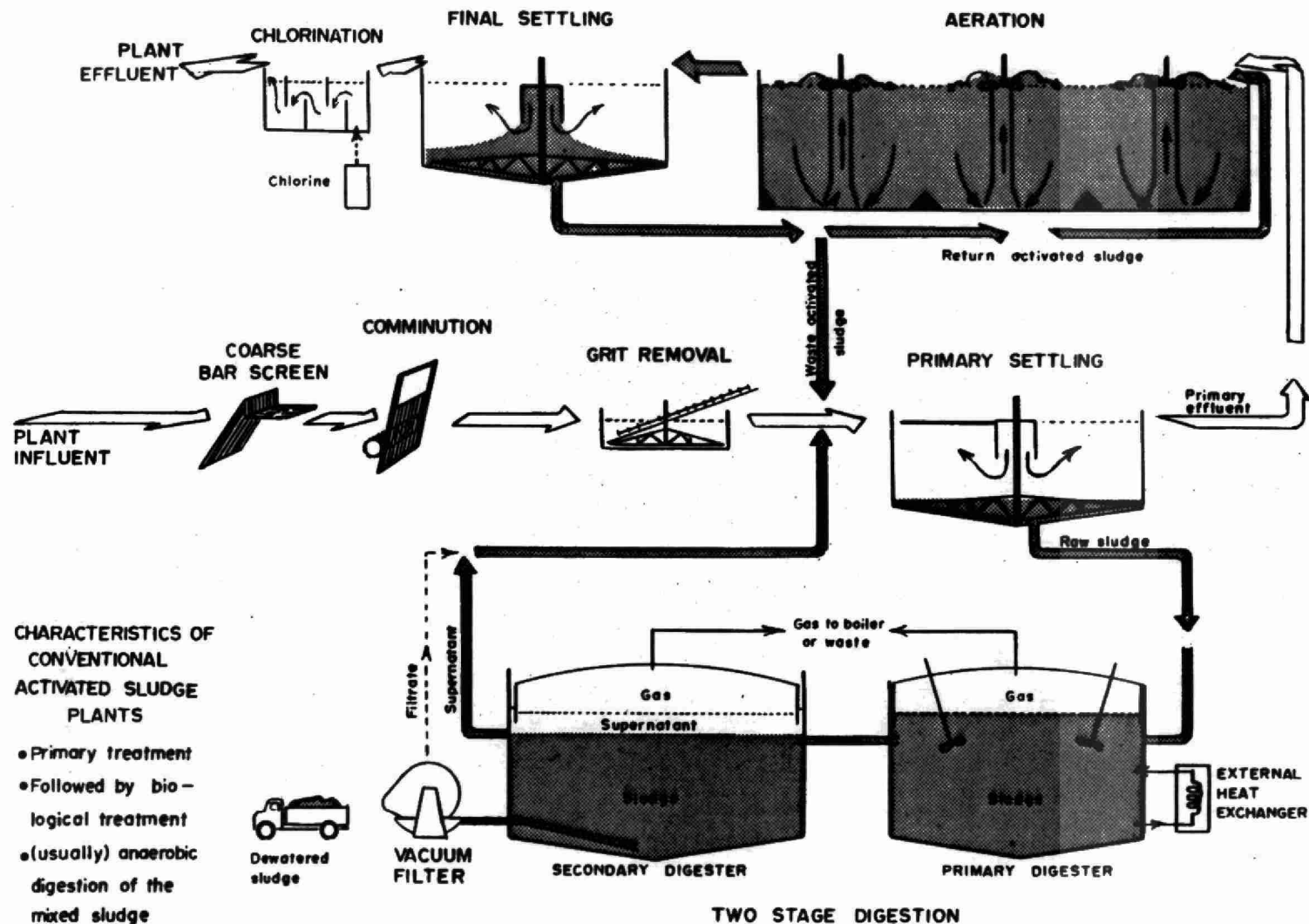
In order to dissolve oxygen into the waste, the activated sludge, the micro-organisms, and the primary effluent are aerated and mixed in an aeration tank. The newly formed organisms are then separated from the treated wastes and settled out in the final clarifier to be recycled and used again. The overflow from this clarifier is a fairly clear liquid which, after disinfection by is discharged to a receiving water. (See Figure 4-1).

In summary, the principal elements of the process are aeration tanks, secondary clarifiers and sludge recirculation and sludge wasting.

FIGURE No. 4-1

CONVENTIONAL ACTIVATED SLUDGE

Shown here with circular centre-fed clarifiers, mechanical aerators, two stage sludge digestion, and sludge dewatering by vacuum filtration.



THE AERATION TANK (See Figures 4-2 and 4-3)

The breakdown of organic materials in the wastewater takes place in the aeration tank. This is achieved by bringing the organic materials into contact with the bacteria in the presence of dissolved oxygen long enough to permit the breakdown to occur. The aeration tanks can be square, rectangular or circular and generally are 3-5 m deep. The tank size depends on the volume of flow to be treated and its ability to detain the incoming flow for a period of 4 to 8 hours. Tanks are generally constructed from concrete, steel, plastic, fibreglass and in some very isolated instances wood has been used. Oxygen is dissolved into the wastewater either by diffused aeration or surface aeration. **It is essential that adequate mixing is provided**, so that the activated sludge is maintained in suspension.

Diffused Aeration

In this type of aeration system, air is blown from the compressors through various types of devices located at the bottom of the aeration tanks, on one or both side walls of the tank. While oxygen is being dissolved into the liquid, a rolling action is generated to ensure thorough mixing and suspension of the activated sludge.

Surface Aeration (Mechanical Aeration)

This technique uses blades of various designs rotating partially submerged at the surface of the liquid with dissolved oxygen from the atmosphere. These devices splash large volumes of liquid over the surface of the tank entraining and dissolving atmospheric oxygen into the tank contents.

Figure 4-2 TYPICAL ACTIVATED SLUDGE TANK

4-4

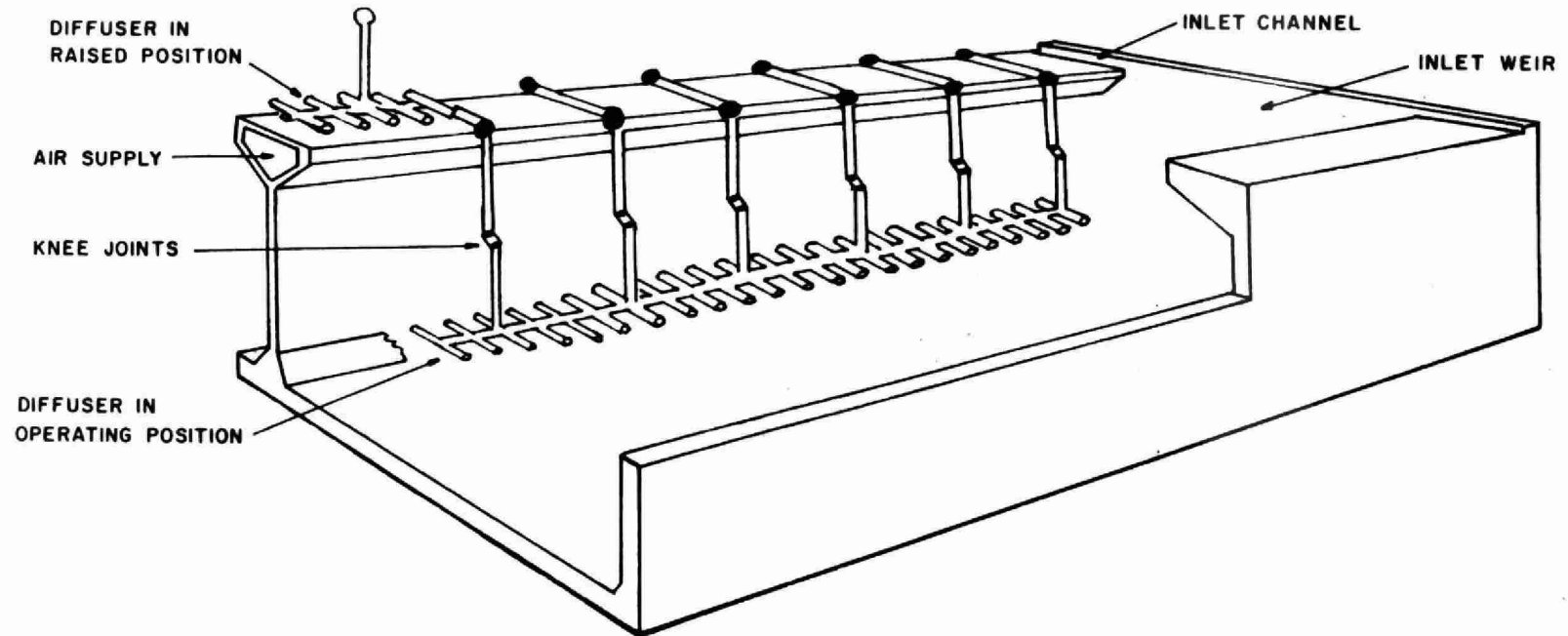
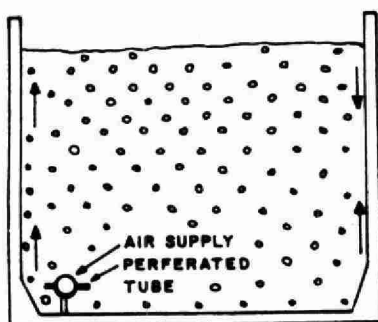
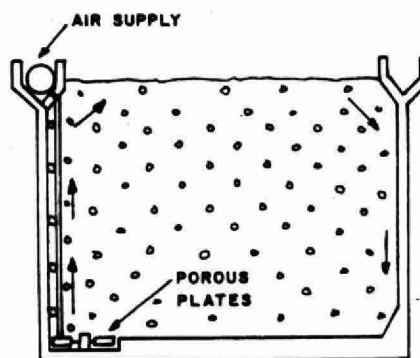


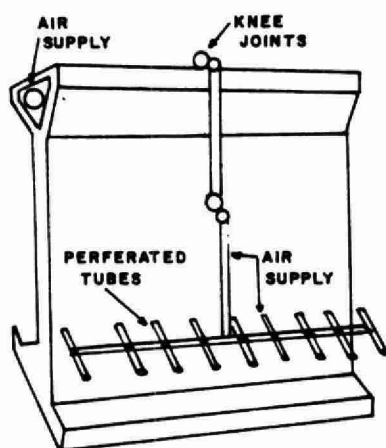
Figure 4-3 AERATING DEVICES



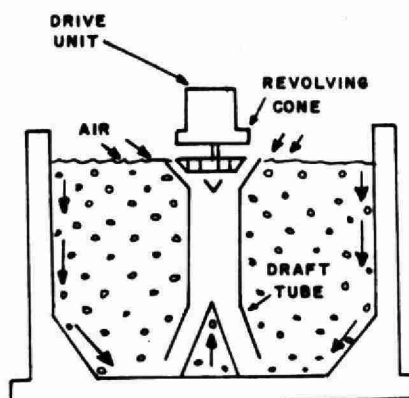
1.
DIFFUSER TUBE
SPIRAL FLOW



2.
POROUS DIFFUSERS
SPIRAL FLOW



3.
SWING DIFFUSER



4.
MECHANICAL AERATOR

This also generates pumping action for the necessary mixing. The amount of oxygen which can be dissolved varies with the speed of the device, its diameter, submergence, and the horsepower of the drive unit. The drive motor ranges from 5 to 150 horsepower.

SECONDARY CLARIFICATION

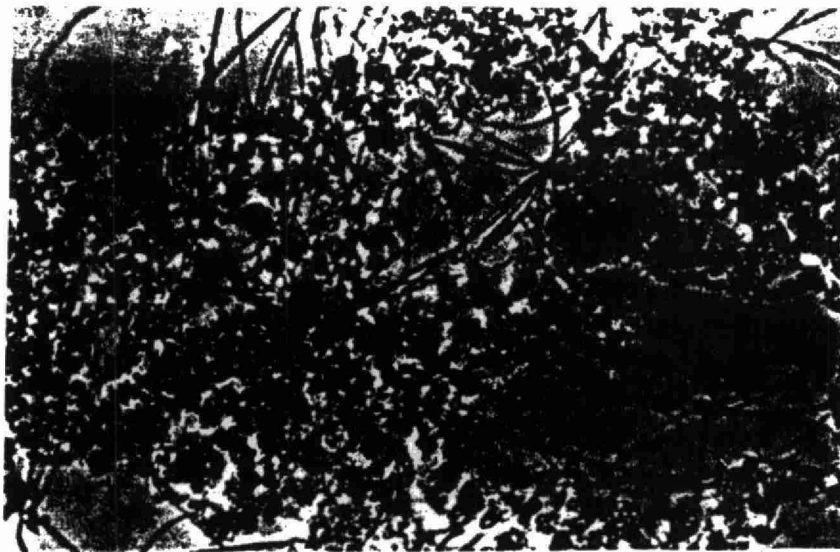
The secondary clarifier, receives the activated sludge from the aeration tank. This unit is essential to the activated sludge process since it is here that the micro-organisms are separated from the now treated wastewater. The micro-organisms in the form of sludge (called activated sludge) settle to the bottom of this clarifier where, with the aid of scraper mechanisms, they are collected and returned to the aeration tank to treat more wastewater. The treated wastewater, with only 10 per cent of its original contaminants remaining, flows over weirs to be disinfected before discharge to receiving water courses.

FACTORS AFFECTING THE ACTIVATED SLUDGE PROCESS

Since the bacteria do the work in the activated sludge system, the factors affecting the system are those affecting the bacteria. As with all life forms, these organisms can only live if conditions remain suitable for their growth. The following are the main considerations in maintaining activated sludge:

1. Since the bacteria are aerobic, oxygen must be present for the organic materials to be broken down. For satisfactory operation of the activated sludge process, a dissolved oxygen concentration in the aeration tank of at least 1 mg/L should be present at all times.
2. A second requirement is food. In this case, the organics in the primary effluent the food supply for the bacteria. The bacteria themselves are the food for some of the higher life forms. Insufficient food will result in cannibalism among the bacteria, while an excess causes a shortage of dissolved oxygen and the growth of filamentous bacteria which are undesirable (Figure 4-5).

Figure 4 - 4 Filamentous Organisms in Activated Sludge



3. It is also important that wastewater entering the activated sludge system contain any materials toxic to microorganisms. The most common source of toxic material is industrial waste discharge, containing:
 - a. Chemicals which result in pH conditions outside the 6.5 to 8.5 range.
 - b. Toxic compounds such as phenol and cyanide.
 - c. Heavy metals such as copper, lead, nickel, chromium, cadmium, etc. in the soluble state.

It is essential that these toxic wastes be eliminated before they enter the activated sludge process. This can be accomplished by:

- a. enforcement of the local Industrial Waste Control Bylaw at the source of the discharge.
- b. pretreatment for removal of the toxic compounds at the plant.

Since pretreatment of the total sewage flow to the plant is considerably more costly than eliminating the toxic compound at its source, the bylaw approach is most often taken.

VARIATIONS OF THE CONVENTIONAL ACTIVATED SLUDGE PROCESS

Variations on the activated sludge process include:

1. Extended Aeration
2. Contact Stabilization or Reaeration
3. Bardenpho Process
4. High Rate (Modified Aeration)
5. Krams Process

EXTENDED AERATION

In the extended aeration process, the aeration tank is larger than the conventional system. Surplus activated sludge produced is wasted to a holding tank for subsequent removal (Figure 4-5). The average retention times in the aeration units are from 12 to 24 hours. Removal of BOD is very high, and the effluent level is frequently below the 15 mg/L objective. However, an ash floc is produced due to the long retention time and the suspended solids content in the effluent from this type of plant is often above the 20 mg/L level. An extended aeration plant requires minimum supervision and may be constructed as the ultimate design for this reason, or may be used as an interim process in a conventional activated sludge plant until the loading increases to the point where it can no longer be effective.

Another form of extended aeration which is often used in rural, low density, or fluctuating population areas, is the **oxidation ditch** which is a race track with a surface beater (Figure 4-6). Sludge removal and return is provided, requiring minimum supervision.

CONTACT STABILIZATION

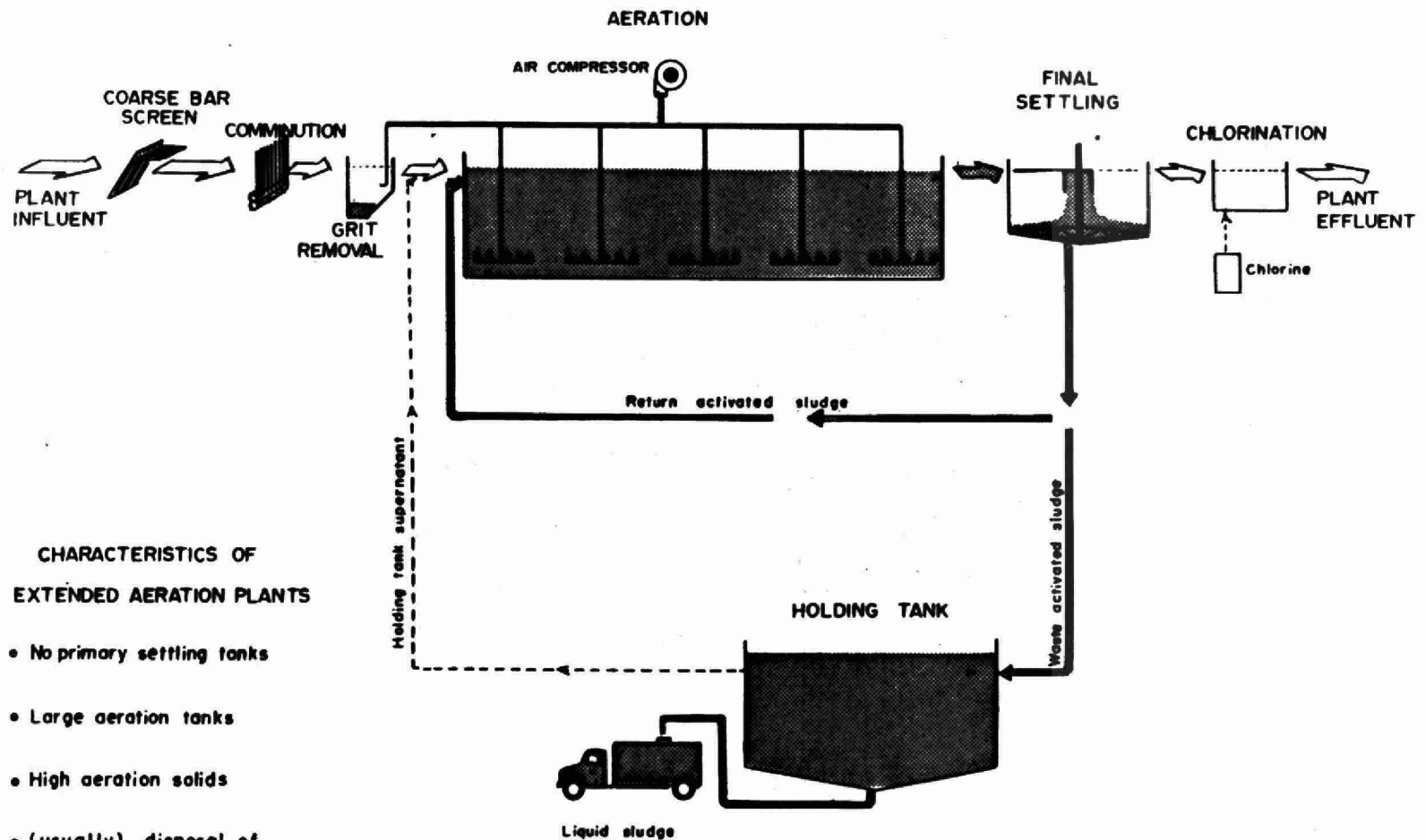
This process is considerably different from the others. It has smaller aeration units and a larger final clarifier (Figure 4-7). The wastewater or primary effluent is mixed with the return sludge for 20 minutes to one hour in a contact tank. In this time the activated sludge **adsorbs** the waste particles. The floc produced is not too dense and passes into a larger final clarifier where the activated sludge and its adsorbed particles are settled. They are then removed to a reaeration tank where normal metabolic processes occurs.

The air requirements that of the conventional process, which is more than 62 m³ of air per kilogram of BOD applied. The contact stabilization process requires high supervision and is hopefully accompanied by low initial construction cost. With the contact stabilization process, applied BOD is determined (62 m³ of air/kg. BOD applied). The required air is divided between the contact tank and the reaeration tank. The detention time in the reaeration tank is approximately 2/3 of the total detention time and the contact tank detention time is 1/3 of the total time required that the air must be applied to the total system at a high rate.

FIGURE No. 4-5

EXTENDED AERATION

Shown here with an aerated grit tank, aeration by diffused air, circular centre-fed clarifier, and a decanted sludge holding tank.



CHARACTERISTICS OF EXTENDED AERATION PLANTS

- No primary settling tanks
- Large aeration tanks
- High aeration solids
- (usually) disposal of raw waste activated sludge.

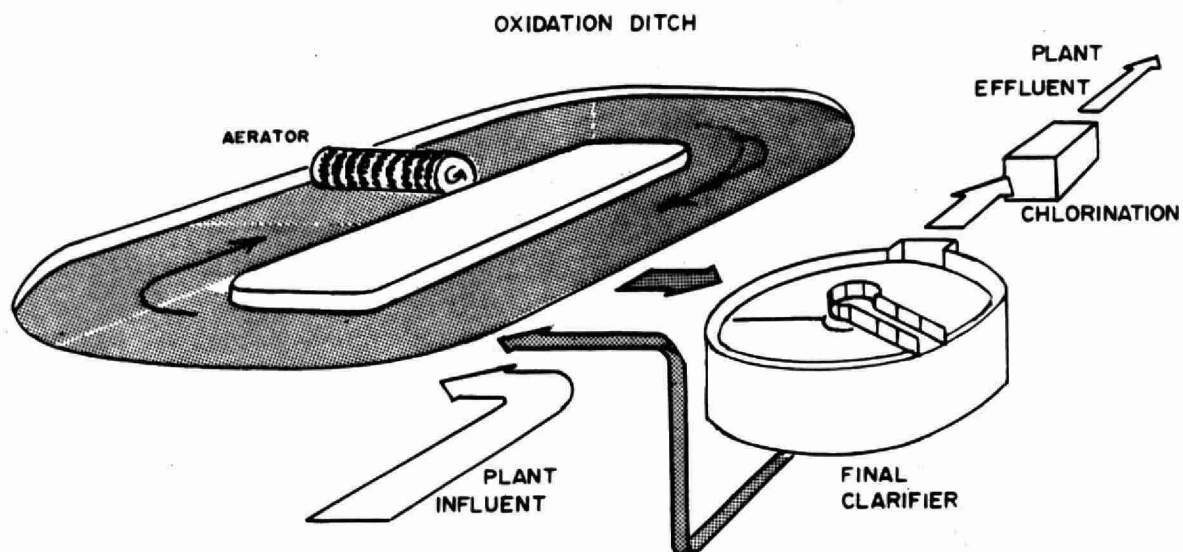
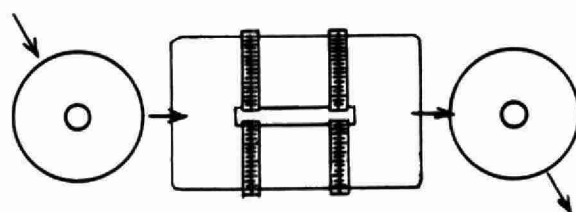
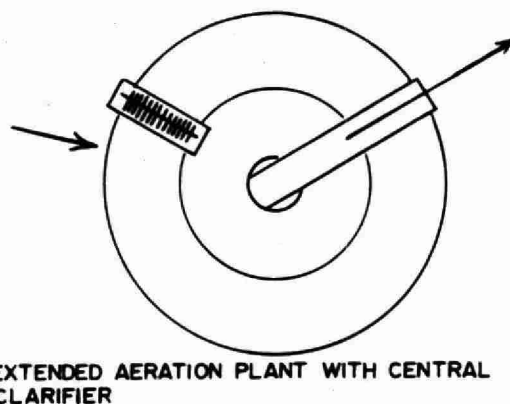
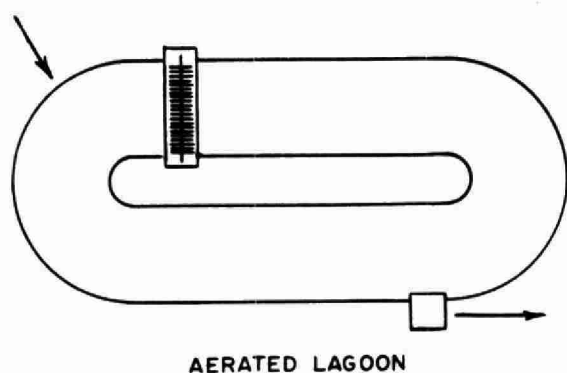
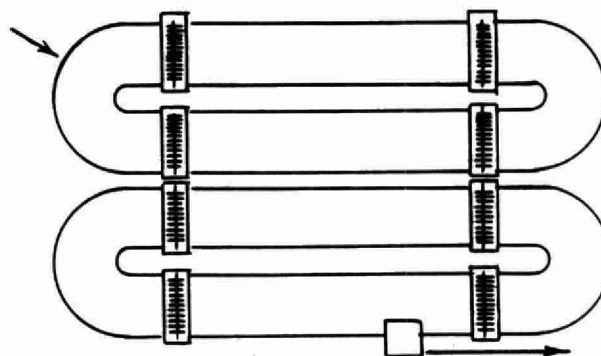


FIGURE No. 4-6 OXIDATION DITCH Shown above as an extended aeration plant.
Other possible configurations are shown below.



CONVENTIONAL ACTIVATED SLUDGE PLANT



AERATED LAGOON WITH TWO OXIDATION DITCHES IN SERIES

The process has certain advantages. A considerable amount of activated sludge is held in reserve and if the monitored raw waste varies, the appropriate amount of sludge can be determined for a balanced F/M ratio. There is also some noticeable saving in the size of structures to be built. Its disadvantages include:

1. The need for more pumping and mechanical equipment
2. The pumping of more air into a smaller tank requiring more involved air diffusion.
3. A competent operator to adjust the process to shock influent loads.

BARDENPHO PROCESS

This unique variation of wastewater treatment can achieve good results in the reduction of nitrogen and phosphorous levels in the effluent. The process occurs in a segmented tank referred to as a Bioreactor.

Primary effluent and return active sludge flow into the initial compartment of the bioreactor, which is anaerobic. In this first phase anaerobic fermentation occurs and sludge is conditioned to metabolize phosphorous. The flow progresses to a second phase that is anoxic (D.O less than 0.2 mg/L) and is combined with a nitrified recycle flow from the third phase. Denitrification occurs during the second phase. The third phase is aerobic. BOD reduction, nitrification and sludge wasting all occur in phase three. Sludge is wasted from this point to ensure that phosphorous remains in the solids and is thus removed. Flow from phase three is directed to phase four which is anoxic. Further denitrification occurs in this phase for the unrecycled portion of the flow from phase three. After the predetermined detention time flow is directed to the fifth phase. Phase five is aerobic and is referred to as the reaeration phase. In phase five CO₂ is stripped from the liquid and sufficient oxygen is dissolved in to prevent additional denitrification occurring in the clarifier.

The mixed liquor flows to a clarifier where liquid/solids separation occurs. The effluent is either disinfected or receives tertiary treatment. The settled solids are pumped back to the bioreactor's first phase.

PROCESS CONTROL TESTS

To progress from the conventional to the contact stabilization process, it is necessary to obtain quick information on what is happening. Tests which enable the operator to make quick changes or spot checks on the process efficiency include:

1. **The half hour settling test.** This test gives a complete picture of the process efficiency, especially if it is plotted in 5-minute intervals.
2. Since the available **dissolved oxygen in the mixed liquor** leaving the aeration units can be significant, a good dissolved oxygen meter is a necessity for quick information.
3. **A pH meter.** pH control is a significant requirement in chemical dosing for phosphorus precipitation.

For details of the DO and solids Tests, see Topics 11 and 12.

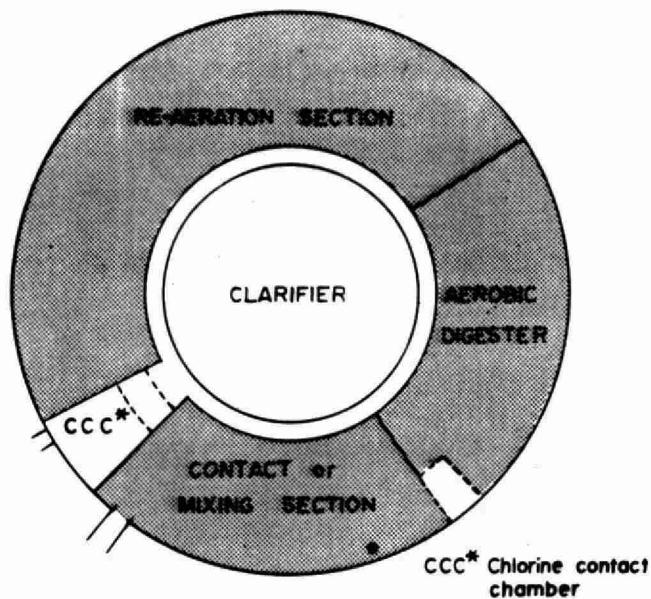


Figure 14a Components are arranged around a central circular clarifier.

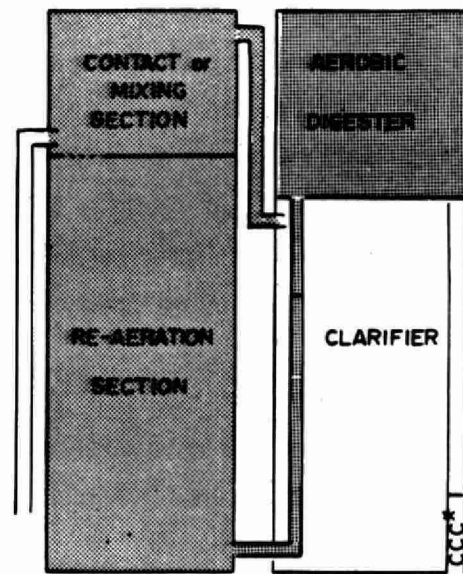
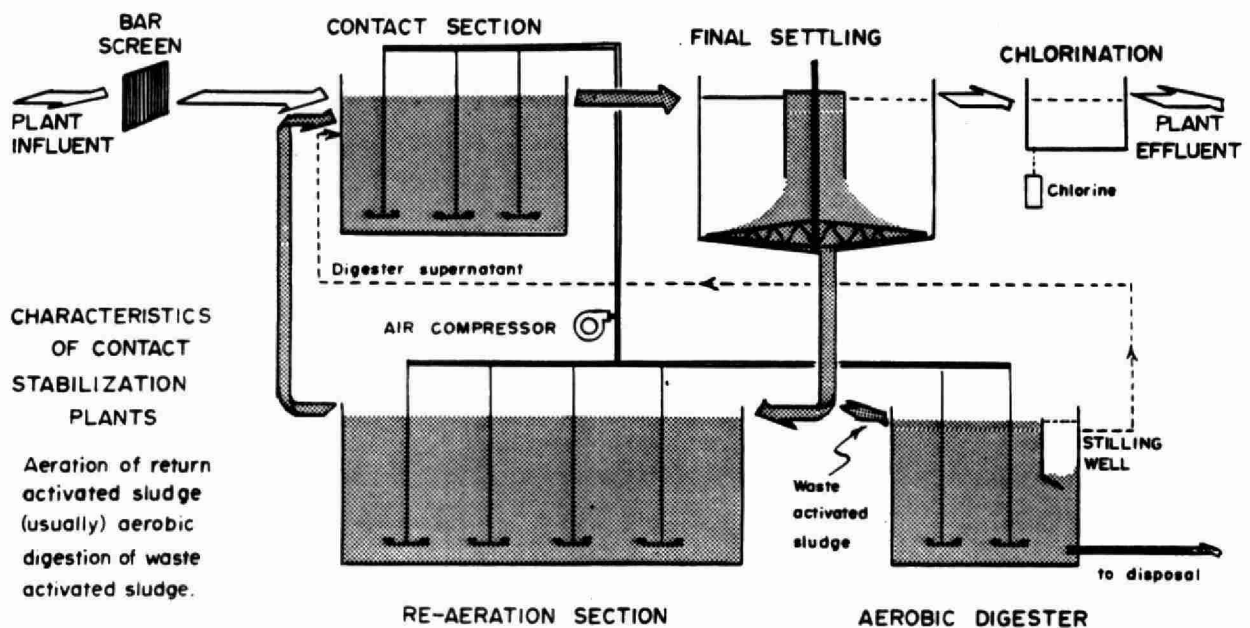


Figure 14b Components are arranged in a rectangular tank.

FIGURE No. 4-7 CONTACT STABILIZATION

Shown here without grit removal facilities since these are not normally supplied as part of the "package".



SUBJECT:

TOPIC: 5

BASIC SEWAGE TREATMENT OPERATION

PREVENTIVE MAINTENANCE

OBJECTIVES:

The trainee will be able to:

1. Define 3 types of maintenance performed within a preventive maintenance program
2. Identify the advantages and disadvantages of a preventive maintenance program
3. List the items required to establish a preventive maintenance program

PREVENTIVE MAINTENANCE

GENERAL

Equipment maintenance is one of the keys to efficient operation of any treatment facility. The equipment that is designed under detailed specifications and operated by qualified personnel will not be efficient unless it is properly maintained. Maintenance performed in any preventive maintenance program can be of 3 types:

1. Breakdown Maintenance
2. Routine Maintenance
3. Frequency Maintenance

Breakdown maintenance refers to the maintenance of equipment only after failure has occurred. This type of maintenance is usually emergency in nature.

Routine maintenance refers to minor maintenance performed that will prevent breakdowns until process equipment can be overhauled at specified frequencies or as required by the manufacturer's recommendations. Maintenance activities include topping up oil levels, checking bearing temperatures, routine greasing, and observing changes in mechanical characteristics of the equipment (e.g. noise, vibration, speed).

Frequency maintenance is maintenance performed during scheduled periods on process equipment that will ensure operation when the equipment is most needed. Types of activities included in frequency maintenance are scheduled overhauls, periodic inspections, and replacement of worn parts. Frequencies are usually specified as operation running time or calendar time.

Because wastewater treatment facilities are combinations of physical, chemical and biological processes, and loadings on process equipment vary daily, weekly and seasonally, it is important that the maintenance activities be well coordinated with plant operations. It is also just as important that the maintenance personnel be fully aware of how the process works and understand what effect untimely maintenance activities will have upon the process.

The value of eliminating or nearly eliminating breakdown maintenance in the treatment plant can be easily appreciated. If treatment is to be continuous, the treatment plant cannot let its major pieces of machinery run until they fail, and then effect repairs, unless it is supplied with an over-abundance of standby equipment.

Preventive maintenance, which by definition is scheduled and planned maintenance, is an alternative to an over-abundance of standby equipment. It has never been economically feasible to provide 100% standby equipment required on peak flow days. By providing for the repair and servicing of equipment during periods of the year when service to the public is not critical, scheduled maintenance can provide a reasonable assurance that breakdowns will not occur when the equipment is needed.

To bring breakdown maintenance to a reasonable level, it is necessary to give the maintenance program the same careful attention that is given to plant operations.

The basic features of a sound maintenance policy are:

1. Responsibility for maintenance must be clearly defined and in the hands of qualified, competent personnel
2. A thorough knowledge of the equipment
3. Proper tools, spare parts, test instruments and shop facilities for performing maintenance
4. Preventive action must be planned and scheduled
5. An adequate system of written records and reports must be used to permit control over the program
6. Good supervision

Because the need for maintenance is something that usually does not show, it is important to make clear and definite assignment of responsibility. When maintenance is everybody's business, equipment breakdown becomes nobody's fault. An assignment of responsibility for maintenance should be delegated to personnel that have the capacity, aptitude and are allowed time for the function.

The fact that the maintenance personnel must be qualified and experienced in maintenance work cannot be over-emphasized.

Knowledge of such important maintenance factors as what constitutes excessive vibration, when bearings should be replaced, when welding constitutes a safe repair, what a loose fit is, and similar points, are only acquired by experience, training and education.

Equipment knowledge can be obtained from instruction manuals issued by the manufacturers of the equipment. These manuals are a result of many years accumulated experience on the part of the manufacturer. Experience is gathered from equipment applications, tests (both field and operational) and operating conditions.

Properly sized shop tools are needed for efficient maintenance procedures. These tools should be of the best quality available. Cheap tools cannot only damage equipment but will be more costly in the long run. Special tools for certain units should be acquired as needed. The tools a mechanic uses and their condition is a good indicator of the calibre of the mechanic. Repair parts should be stocked according to the number of machines or equipment installed and the expected life of the equipment parts. (The manufacturer's suggestions are often helpful).

Consideration should be made when purchasing spare parts as to the priority allotted the individual piece of equipment. Priority rating is established by asking the following questions:

1. Is this piece of equipment vital to the process?
2. What maximum down time can be tolerated if the equipment fails at the worst possible time?
3. Is standby equipment readily available?
4. Can other equipment fail due to load changes caused by a failure of this piece of equipment?

Preventive maintenance management problems will require less decision making if priorities of maintenance are pre-planned. To maintain capital equipment will usually produce one of two results, either the maintenance cost will be high or the equipment will be poorly maintained causing frequent breakdowns.

For this reason, equipment can be divided into three priority groupings and maintenance dollars spent to best advantage.

The groupings are as follows:

- Priority 1 - Equipment that is vital to the process and without such equipment the process cannot achieve desired results.
- Priority 2 - Equipment that is considered standby equipment, but may be as reliable as Priority 1 equipment over shorter periods of time.
- Priority 3 - Equipment that is not vital to the process, which serves a function other than the process. Wastewater treatment facilities are usually designed for future flow increases and, therefore, the number of pieces of equipment in Priority 1 should be relative to the current flow loadings.

Preventive maintenance is successfully practised when it is properly planned and performed according to a prearranged schedule. It requires the same attention and importance as the transfer of sludge, digester temperature, or the cleaning of bar screens. Unless preventive maintenance is routinely performed and regarded as a plant operation, as are actual plant operations, breakdown maintenance cannot be avoided.

The planning of a preventive maintenance program, therefore, requires that equipment items be studied to determine the maintenance operations required and the frequency of these operations. This is determined from an analysis of service conditions of the equipment, from your operating experiences, from others operating experiences and from equipment manufacturer's recommendations. Each equipment item or unit must be studied individually, for even similar pieces of equipment may have different care requirements because of location or service.

To carry out and administer a maintenance program effectively requires a minimum of records and forms, yet such records are very important to successful maintenance for the following reasons:

1. Provide data for accurate budget forecasting
2. Prove compliance with manufacturer's instructions
3. Validate warranty conditions
4. Evaluate equipment performance
5. Highlight recurring faults
6. Establish maintenance frequency
7. Comparison of existing equipment
8. Evaluate the maintenance program

In summary, continuity of service and performance is of prime importance in a wastewater treatment facility. Good maintenance is good management and operation. A preventive maintenance program is scheduled routine and frequency maintenance that will cut breakdowns and unplanned equipment outages to a minimum, as well as keeping equipment operating at peak efficiency. No treatment facility is too small to install or institute a preventive maintenance program, and no community is rich enough to be able to afford not to take care of its equipment.

The Preventive Maintenance Program

Routine and frequency maintenance function can often be performed simultaneously in a preventive maintenance program. After initial planning has been considered, a card system can be set up for each maintenance item to be performed on a piece of equipment. The card must contain all vital information about the equipment as found on the equipment plate or in the manufacturer's manual. Other information is also necessary such as lubricant specifications, allowable clearances, bearing part numbers, belt sizes, etc. The card should be as complete in detail as possible so that no assumptions will be made and the wrong items substituted during service or repair. Also, special information service should be noted on the card. Cards then should be divided into intervals of maintenance frequency on either a calendar basis or a time basis. Colour coding the cards usually helps maintenance personnel identify the type of maintenance to be performed.

An example follows:

	<u>Colour</u>	<u>Frequency of Maintenance</u>
1.	White	Weekly
2.	Blue	Monthly
3.	Green	Quarterly
4.	Orange	Semi-annually
5.	Yellow	Yearly

The tasks required are also contained in the information on the card. Then the maintenance personnel simply read the instructions, perform the work, sign the card and note any irregularities. When in operation, the system works well, however, the benefits will be realized only if adequate supervision is employed to run such a system.

SUMMARY

The general items required to establish a preventive maintenance program should include:

1. Routine maintenance activities
2. Frequency maintenance activities
3. Complete diagrams and "as built" prints of the facility
4. Process equipment data cards and operating manuals
5. A recordkeeping and reporting system

A good preventive maintenance program will:

1. Cut down on costly equipment breakdowns
2. Reduce the need for 100% standby equipment
3. Prevent the loss of vital process stages that would reduce effluent quality
4. Provide effective and efficient operation
5. Utilize manpower more effectively
6. Increase the cost of stocking replacement parts
7. Comply with manufacturer's warranties
8. Decrease equipment "down-time"
9. Equalize the maintenance workload
10. Require competent and qualified personnel

APPENDIX TO TOPIC 5

MAINTENANCE FREQUENCY GUIDELINES

INTRODUCTION

Attached are suggested maintenance frequency guides. The purposes of these are to:

1. establish between co-ordinator and facility personnel a common date for minor and major overhaul
2. to establish a schedule that will provide an overhaul time to facilitate frequency maintenance
3. to establish a schedule for repairs so that parts required can be purchased before hand
4. to indicate a guide to maintenance care

For the purposes of maintenance, units of a system must be treated separately. Every component of the system cannot be covered under one maintenance inspection for two reasons:

1. The components differ in complexity
2. The components have different time intervals between inspections

This segregation also lends itself to grouping of inspection frequency cards under component rather than system.

The methods recommended are as follows:

1. A complete copy of the maintenance frequency guides.
2. Sufficient cards to make a file in various colours; example:
 - a. white - weekly
 - b. blue - monthly
 - c. pale green - quarterly
 - d. orange - semi-annually
 - e. yellow - yearly

3. The file rack should be divided into twelve portions, namely the months of the year, and the cards placed in the appropriate monthly rack.
4. As a task advocated on the card is completed, the reverse side of the card is dated and initialled. If required, a repair and alterations card is then forwarded to the program co-ordinator.
5. In the event of a breakdown before the due inspection date arrives, a repair and maintenance card is submitted, if appropriate, to the program co-ordinator.

MAINTENANCE FREQUENCY METERING GUIDE

	1	2	3	6	1	18	2	3	5
WKY	MTH	MTH	MTH	MTH	YR	MTH	YR	YR	YR

METERS AND INSTRUMENTATION

PRIMARY DEVICES

FLOW

Pitot Tube					X				
Rotameter			X						
Nozzles								X	
Venturi					X				
Dall Tube					X				
Parshall Flume					X				
Venturi Flume					X				
Weirs					X				
Orifice Plates							X		
Magnetic Flow Tubes						X			
Propeller Type					X				

LEVEL

Float			X						
Displacer					X				
Probe			X						
Sealed Probe					X				
Sonic					X				

TEMPERATURE

Thermocouple
Resistance
Filled Systems Mercury
Filled Systems Vapour

	1	2	3	6	1	18	2	3	5
WKY	MTH	MTH	MTH	MTH	YR	MTH	YR	YR	YR

PRESSURE

Bourdon Tubes					X				
Bellows					X				
Diaphragm					X				
Submerged Bellows					X				
Submerged Diaphragm					X				
Bubbler (Air Set and Rotameter)					X				
Manometer (Visual)					X				
Manometer Mercury (Non Visual)					X				

INDICATORS (ELECTRICAL)

Moving Coil				X				X	
Moving Iron				X				X	
Dynamometer				X				X	
Electro Static				X	X				
Disc Magnetic				X					
Hot Wire				X	X				

RECORDERS (ELECTRICAL)

Moving Coil				X				X	
Moving Iron				X				X	
Dynamometer				X				X	
Electro Static				X	X				
Disc Magnetic				X					
Hot Wire				X	X				

INDICATORS (MECHANICAL)

X

RECORDERS (MECHANICAL)

X

	1	2	3	6	1	18	2	3	5
	WKY	MTH	MTH	MTH	YR	MTH	YR	YR	YR

METERS AND INSTRUMENTATION SECONDARY DEVICES

Amplifiers					X				
------------	--	--	--	--	---	--	--	--	--

TRANSMITTER & RECEIVER ELEMENTS

1 Pneumatic			X						
2 Vacuum	X								
3 Electric									
a) Pulse				X					
b) Voltage					X				
c) Current					X				
d) Induction					X				
4 Electronic (Frequency)					X				

TELEMETERING RECEIVERS

1 Indicators					X				
2 Recorders				X					

INTEGRATORS

1 Mechanical					X				
2 Electrical					X				

<u>ANALOG SYSTEMS (Simple)</u>					X				
--------------------------------	--	--	--	--	---	--	--	--	--

<u>DIGITAL SYSTEMS (Simple)</u>					X				
---------------------------------	--	--	--	--	---	--	--	--	--

<u>POTENTIOMETRIC SYSTEMS (Bridge Rec.)</u>					X				
---	--	--	--	--	---	--	--	--	--

	1	2	3	6	1	18	2	3	5
WKY	MTH	MTH	MTH	MTH	YR	MTH	YR	YR	YR

INSTRUMENT CONTROLLED OPERATORS

Pneumatic				X					
Hydraulic Valves				X					
Electric Valves					X				

CONTROLLERS

1 Pneumatic				X					
2 Electric					X				

<u>INSTRUMENT GALVANOMETER SYSTEMS</u>					X				
--	--	--	--	--	---	--	--	--	--

<u>INSTRUMENT SERVO SYSTEMS</u>					X				
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<u>PYROMETERS</u>					X				
-------------------	--	--	--	--	---	--	--	--	--

**INDUSTRIAL AND ELECTRONIC CONTROL
MAINTENANCE FREQUENCY GUIDES**

	1	2	3	6	1	18	2	3	5
	WKY	MTH	MTH	MTH	YR	MTH	YR	YR	YR

INDUSTRIAL ELECTRONICS CONTROLS

Pressure Bourdon Tube			X					**	
Bellows			X					**	
Diaphragm			X				**		
Bubbler			X				**		
Level Floats			X					**	
Float Switches			X				**		
Probes			X				**		
Sealed Probes			X					**	
Temperature Thermocouple					X			**	
Resistance					X			**	
Flow Rotameter Rate	X						**		
Differential Pressure	X						**		
Timers and Time Delay Units			X				**		
Relays			X				**		
Contactors & Starters (Fractional H.P.)			X				**		
Telemetry Control - Wire			X				**		
Instrument Initiated					X			**	
Heat Exchangers - General				X			**		
Gas - Oil Changeover				X			**		
Reacto Speed Controls					X			**	
Ross, Singer, Clayton Control Valves							X	**	
Fluid Clutch							X	**	
EMI Controls					X			**	
Dynumatic Clutch					X			**	
Motorized Valves							X	**	
Solenoid Valves							X	**	
Altitude Valves							X	**	
Liquid Rheostats (Flowmatcher)						X		**	

** Major Overhaul and Calibration

	1	2	3	6	1	18	2	3	5
	WKY	MTH	MTH	MTH	MTH	YR	MTH	YR	YR
ELECTRONICS									
Amplifiers Tubes					X			**	
Solid State (Transistors)					X				
Power Transistors					X				
Power Supplies - Unregulated					X			**	
- Regulated					X			**	
Silicon Controlled Rectifiers					X				
*Induction and Dielectric Heaters									
Relays - Photo Electric			X				**		
Heat Exchanger Controls									
(Electronic)			X				**		
Regulators Speed & Voltage									
(Electronic)			X				**		
Thyratrons			X					**	
Oscillators					X			**	
Inverters					X			**	
Control Servo Mechanisms				X				**	
Density Meters (Nucleonic)					X			**	
Radio Transmitters &									
Receivers	X								
Digital Systems				X					
Analog Systems	X								
Electronic Instrumentation	X							**	
Telemetering Control:									
Radio			X				**		
Pulse Type Control:									
Chlorinators	X							**	
* Future									
** Major									

**ELECTRICAL MOTOR AND GENERATOR
MAINTENANCE FREQUENCY GUIDE**

1	2	3	6	1	18	2	3	5
WKY	MTH	MTH	MTH	MTH	YR	MTH	YR	YR

D.C. GENERATORS (COMPOUND & SHUNT)
A.C. POLYPHASE AUXILIARY GENERATORS

Inspect bearing & collector rings or commutator
(if running frequently)

X	X
Test insulation with megger	X

Lubricate sparingly	X
---------------------	---

Flush out old grease and relubricate	X
Blow out or vacuum	X

Clean or dress collector rings or commutator	
Test brush pressure and fit	X

Test voltage, current and Frequency output against speed	X
---	---

MAJOR OVERHAUL

Remove armature, clean and varnish	X
Clean Stator and varnish	X

Flush out bearings and housings	
Renew bearings if necessary	X

Dress collector rings or commutator	
Undercut commutator if necessary	X

Check brush pressure and fit	
Renew if necessary	X

Reassemble and check for air gap	X
----------------------------------	---

Check voltage, current and frequency output against speed	X
--	---

Megger insulation	X
-------------------	---

Clean and paint exterior	X
--------------------------	---

	1	2	3	6	1	18	2	3	5
	WKY	MTH	MTH	MTH	YR	MTH	YR	YR	YR

A.C. POLYPHASE

Squirrel Case and Wound Rotor Induction
(Including Synchronous Motors) 50 to 300 H.P.

Inspect bearings
and collector rings X

Test insulation with megger X

Lubricate sparingly X

Flush out old grease and relubricate X

Blow out or vacuum X

Clean or dress collector rings X

Test brush pressure and fit X

MAJOR OVERHAUL

Remove armature, clean
and varnish X

Clean stator and varnish X

Flush out bearings and examine, re-lubricate

Renew bearings if necessary X

Dress collector rings and
check brush fit and pressure
Renew brushes if necessary X

Re-assemble and check for air gap X

Check full load current
against line voltage. Megger X

Clean and paint exterior X

	1	2	3	6	1	18	2	3	5
WKY	MTH	MTH	MTH	MTH	YR	MTH	YR	YR	YR

Squirrel case and wound
rotor inductions motor
(including Synchronous
motors) 15 to 40 H.P.

Inspect bearing and
collector rings X

Test insulation with megger X

Lubricate X

Blow out or vacuum X

Clean collector rings
Test brush fit and pressure X

MAJOR OVERHAUL

Remove armature
clean and varnish X

Clean stator and varnish X

Flush out bearings and
 housings and relubricate

Renew bearings if necessary X

Dress collector rings and
check brush fit and pressure

Renew brushes if necessary X

Re-assemble and check for
air gap X

Clean and paint exterior X

	1	2	3	6	1	18	2	3	5
	WKY	MTH	MTH	MTH	MTH	YR	MTH	YR	YR

A.C. Squirrel case,
wound rotor and Synchronous 1 to 10 H.P.

Inspect bearings and
collector rings X

Test insulation with megger X

Lubricate X

Blow out or vacuum X

Clean collector rings
Test brush fit and pressure X

MAJOR OVERHAUL

Remove armature,
clean and varnish X

Clean stator and varnish X

Flush out bearings and
housing and re-lubricate
Renew bearings if necessary X

Dress slip rings and
check brush fit and pressure
Renew brushes if necessary X

Re-assemble and check
for air gap X

Clean and paint exterior X

1	2	3	6	1	18	2	3	5
WKY	MTH	MTH	MTH	YR	MTH	YR	YR	YR

FRACTIONAL H.P. MOTORS

Various Types

Split - phase induction
 Resistance start
 Reactor start
 Capacitor start
 Capacity run
 Repulsion run
 Repulsion compensated
 Repulsion start induction
 Repulsion induction
 Shaded pole
 Universal

Inspect bearings and commutator
 Test insulation with meggar
 Lubricate
 Blow out or vacuum
 Clean commutator (on motors using same)
 Test brush fit and pressure

MAJOR OVERHAUL

Remove armature, clean and varnish	X
Clean stator and varnish	
Clean starting winging contacts	X
Flush out bearings and housings	
Re-lubricate Renew bearings if necessary	X
Dress commutator and check brush fit and pressure	
Renew brushes if necessary	X
Re-assemble and check for air gap	X
Clean and paint exterior	X

**AUXILIARY ENGINEERS AND
ASSOCIATED EQUIPMENT
MAINTENANCE FREQUENCY GUIDE**

	1	2	3	6	1	18	2	3	5
	WKY	MTH	MTH	MTH	MTH	YR	MTH	YR	YR

**AUXILIARY ENGINES AND EQUIPMENT
TO BE COVERED UNDER DIESEL AND
GASOLINE SECTION**

Minor Inspection - 1 yr.

Major Inspection - 5 yr.

Electric starters				X	X				
Electric generators				X	X				
Fuel pumps single and monobloc type						X			
Fuel lift pumps, electrical or mechanical									
									X
Fuel atomizers						X			
Fuel rack solenoid									
Valve train						X			
Speed, water temperature, lube oil, pressure switches (safety)									X
Fan & Belt cooling system									X
Electric or Thermostatic Regulating Valves									X
Controls-Start/Stop, Test									X
Batteries & chargers									X
Fuel supply system (filters*) leaks									X*
Radiators or Heat Exchangers									X
Timing Engine						X			

**AUXILIARY ENGINEERS AND
ASSOCIATED EQUIPMENT
MAINTENANCE FREQUENCY GUIDE**

	1	2	3	6	1	18	2	3	5
	WKY	MTH	MTH	MTH	MTH	YR	MTH	YR	YR

**AUXILIARY ENGINES AND EQUIPMENT
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Electric generators				X	X				
Fuel pumps single and monobloc type						X			
Fuel lift pumps, electrical or mechanical									X
Fuel atomizers						X			
Fuel rack solenoid									
Valve train						X			
Speed, water temperature, lube oil, pressure switches (safety)									X
Fan & Belt cooling system									X
Electric or Thermostatic Regulating Valves									X
Controls-Start/Stop, Test									X
Batteries & chargers									X
Fuel supply system (filters*) leaks									X*
Radiators or Heat Exchangers									X
Timing Engine						X			

	1	2	3	6	1	18	2	3	5
WKY	MTH	MTH	MTH	MTH	YR	MTH	YR	YR	YR

GASOLINE EQUIPMENT

Minor Inspection - 1 yr.

Major Inspection - 5 yr.

Electric starter				X					
Electric generator				X					
Carburettor			X						
Distributor or Magneto			X						
Fuel lift pump - mechanical									
or electrical	X								
Valve train						X			
Engine ignition timing				X					
Fan & belt cooling	X								
Thermostatic or electric									
regulating valves	X								
Speed, water temperature,									
lube oil pressure									
switches (safety)		X							
Batteries	X								
Battery charger	X								

	1	2	3	6	1	18	2	3	5
	WKY	MTH	MTH	MTH	MTH	YR	MTH	YR	YR

AUXILIARY ENGINES AND EQUIPMENT TO BE COVERED UNDER DIESEL AND GASOLINE SECTION

DRIVEN UNITS

Minor Inspection - 1 yr.									
Major Inspection - 5 yr.									
Clutch power take off			X		M				
Right angle gear drives	X								
Universal drive shaft			X						
Solid coupling drives				X					

PANELS-Engine CONTROL

Minor inspection									
All instruments connected to engine, oil, water,etc.	X								
Wiring connections	X								

GENERATOR DISTRIBUTION

Load check	X								
Voltage meter instr.	X								
Amps meter instr.	X								
Freq. meter instr.	X								
Battery charging meter instr.	X								

GENERATORS

Minor Inspection - 1 yr.									
Major Inspection - 3 yr.									
Slip rings			X						
Brushes			X						
Wiring connections	X								
Fan blades			X						
Bearings				X	M				
Rotor				X					
Stator				X					

	1	2	3	6	1	18	2	3	5
	WKY	MTH	MTH	MTH	YR	MTH	YR	YR	YR

INSTALLATION

Major inspection on start up

Unit Foundation						X
Alignment of Engine & Generator						X
Alignment of Engine & Right angle gear drives						X
Exhaust system						X
Water supply system						X
Testing unit operation 2-4 hrs						X
Defects in normal operation of unit						X
Operation of driven unit						X

TURBOCHARGERS

Minor inspection - 1 yr.

Major inspection - 5 yr.

Turbochargers						X
Oil levels						X
Air volume						X
Exhaust temperature						X
Expansion rings						X
Water cooling						X

M - Minor

The above minor inspections should be carried out yearly. Major inspections are based on 5 years inspection unless condition and hours in operation warrant inspections before this time.

MECHANICAL EQUIPMENT MAINTENANCE FREQUENCY GUIDE

	1	2	3	6	1	18	2	3	5
	WKY	MTH	MTH	MTH	MTH	YR	MTH	YR	YR

MECHANICAL EQUIPMENT

* Aerators Diffusers				X					
* Aerators Mechanical				X					
* Air Lifts					X				
* Altitude valves					X				
* Barminutors				X					
* Bearings - mech. seal						X			
* Blowers					X				
* Boilers					X				
* Centrifugal pumps & sewage				%		X			
* Centrifugal pumps - water					%			X	
* Chain Blocks			X						
* Check valves				X					
* Chemical feeders			X						
* Clarifiers					X				
* Coil filters				X					
* Comminutors				X					
* Condition tanks (sludge)					X				
* Conveyors					X				
* Detritors					X				
* Diaphragm pumps				X					
* Digesters					X				
* Digest gas lines (pressure tests)			X						
* Ejectors					X				
* Electric hoists			X						
* Exhaust or vent fans					X				
* Flame arresters			X						
* Float switches			X						
* Gas pumps					X				
* Gate valves				X					
* Gear reducers				X					
* Grit rakes					X				
* Heat exchangers					X				
* Hydraulic, pneumatic solenoid					X				
* Micro strainers					X				
* Mixers					X				
* Motorized valves					X				
* Organic repair pumps				X					
* Pressure reducing valves				X					

	1	2	3	6	1	18	2	3	5
WKY	MTH	MTH	MTH	MTH	YR	MTH	YR	YR	YR

MECHANICAL EQUIPMENT - (Cont'd...)

* Pressure regulating valves (Water)				%	X				
* Plug valves					X				
* Plunger pumps					X				
* R/A Geare					X				
* Rotogrators				X					
* Sand filters					X				
* Scales					X				
* Screens (Mechanical)					X				
* Skip hoists			X						
* Space heaters - gas					X				
* Sub stations - major									X
* Sub stations - visual					X				
* Trickling filters					X				
* Turbine pumps					%			X	
* Vacuum/Press relief valves					X				
* Vacuum pumps				X					
* Vari-drives				X					
* Waste gas burners				X					
* Water conditions					X				
* Flowmeters				X					

* Inspect, repair, comment

% Inspect, comment

Unattended Pumping Stations Under Warranty (1st. 3 months)

All controls where attended 24 hours a day (3 months)

PUMPING STATIONS MAINTENANCE FREQUENCY GUIDE

PUMPING STATIONS

MAINTENANCE FREQUENCY GUIDE

White Cards - weekly

1. Lights and blower should operate when cover is open. Make sure manual switch is off when leaving station as excessive ventilation will cause condensation.
2. Check air supply at compressor storage tank.
3. Check rate of bubble flow.
4. Check operating levels.
5. Check sump pump operation.
6. Check dehumidifier for icing and operation.
7. Check filter on seal water supply by bleeding seal while pump is idle. (DO NOT OPEN BLEEDER VALVE WHILE PUMP IS OPERATING). Clean filter when necessary.
8. Check overload reset buttons on all pumps.
9. Listen for peculiar noises.
10. Feel pumps and rotors in operation for heating.
11. Observe action of check valves.
12. Test standby pump operation.
13. Check mechanical seal for leakage. (DO NOT RUN PUMP WITH SEAL LEAKING, AS THIS CAN HARM THE SLEEVE OR SHAFT).
14. Be sure station can operate successfully until next visit.

Blue cards - monthly

1. Close and open all gate valves.
2. Check sump pump operating and clean sump pit.
3. Check bubbler line for leaks or blockage.
4. Purge bubbler line by turning adjusting knob on regulator to provide greater flow of air. Reset as originally found.
5. Comment on bubbler system and dehumidifier.

Green cards - 3 months

1. Clean filter on compressor intake.
2. Clean filter bowls or sight glasses on bubbler system.
3. Assess and replace supplies of seal filter elements and parts.
4. Compare operating levels with those 3 months previous to ascertain possible control failures.
5. Clean pressure gauge lines on pumps.
6. Clean filter (seal) lines on pumps.
7. Place orders for expendable equipment on a 3 month prior order basis.
8. Contact Co-ordinator on condition of operation.

Orange cards - 6 months

1. Inspect discharge check valves.
2. Take impeller clearances and check impeller fastening. (Bring subject to attention of co-ordinator for advisement)
3. Check bubbler pipe in wet well and replace if warranted.

Yellow cards - yearly

1. Lubrify motor bearings.
2. Check motor for cleanliness. Ensure air passages are free.
3. Check stator for evidence of heating at connection lugs aged or cracked insulation on windings.
4. Check motor control for signs of worn, pitted or dirty contacts.
5. Check load readings against nameplate data.
6. Thoroughly inspect air compressor. Replace any parts that show signs of wearing.
7. Check falk coupling springs. Clean and lubricate.
8. Check condition of Cathodic protection.
9. Take equipment inventory. Data card correction.
10. Take spare parts inventory.
11. Take inventory of tools and evaluate condition.
12. Evaluate pumping time. (Flow increase or decrease).

SUBJECT**SEWAGE TREATMENT OPERATION****TOPIC 6****DIGESTION OF SLUDGE****OBJECTIVES:**

The trainee will be able to:

1. Explain the main purpose of sludge digestion.
2. Recall two processes employed for the digestion of sludge.
3. List four critical factors in sludge digestion.
4. Discuss the factors affecting the operation of:
 - a) single stage digestion
 - b) two stage digestion
 - c) aerobic digestion
5. Recall the tests and records required to maintain process control in single stage digestion.

DIGESTION OF SLUDGE

PRIMARY PURPOSE

The primary purpose of sludge digestion is to reduce the complex organic matter present in the raw sludge (removed by sedimentation processes) to a simpler non-objectionable state. Digestion produces a sludge more amenable to dewatering, without nuisance, and renders the sludge fit for easy disposal by lagooning, dewatering on sand beds, and by direct application to farmlands, golf courses, parks, etc. Digestion also reduces the volume of sludge and in doing so produces gas which can be utilized for heating purposes or gas engine operation. Sludge digestion can be either anaerobic, described below, or aerobic, described starting on Page 6-22.

THE ANAEROBIC DIGESTION PROCESS

In the anaerobic digestion process, the sludge can be considered as consisting of two portions: a solids portion, composed of material settled in the clarifiers, and a **liquid** portion, containing materials in actual solution. The concentration of material in true solution is relatively low in raw sludge entering the digester, and is essentially no higher than that contained in sewage entering the treatment plant. Basically, the dissolved materials are the only ones which the bacteria may utilize as food.

After sludge is sent to the digester(s), the organic materials, contained mostly in the solid portion of the sludge, are slowly hydrolysed and brought into solution by enzymes present in the digester (See Figure 6-1). Under normal conditions of operation, the organic matter is then quickly broken down into volatile organic acids by a group of bacteria commonly called "acid formers". The organic acids are in turn decomposed into carbon dioxide and methane by a second group of bacteria commonly called the "methane formers". Because of this decomposition, the quantity of organic matter actually in solution normally remains low. There is, however, a build-up of certain salts in solution such as ammonium, calcium, and magnesium bicarbonates which result from the breakdown of proteins and soaps. In a digester, these salts produce the natural buffers, which normally remain fairly constant at about 1,000 to 3,000 mg/l as calcium carbonate, depending on the sludge concentration.

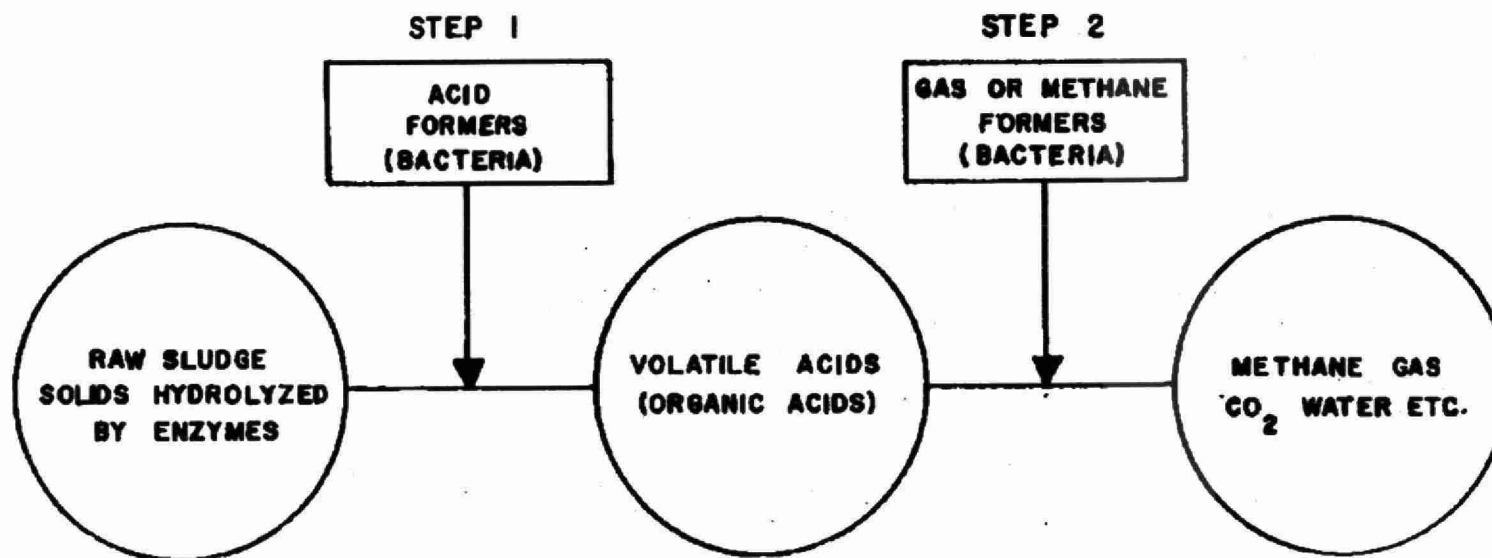
When unbalanced digestion conditions exist, the methane-producing organisms cannot remove the volatile acids as quickly as they are formed and a build-up of the volatile acids results. This build-up can take place very rapidly, and in several days the total concentration of the volatile acids in solution can be more than doubled (See Figure 6-1), and note that failure occurs in the critical second phase when the gas methane forming organisms do not break down volatile acids fast enough.

pH ranges from 6.8 to 7.2 have proved effective in maintaining a good digestion process. Experience has shown that digester process failure will be far advanced before the pH will indicate a problem. The volatile acids test has proved more effective in avoiding a process breakdown. Volatile acid concentrations between 200 mg/l and 500 mg/l will indicate satisfactory operation. A change from 300 mg/l to 500 mg/l might indicate a developing problem but until a concentration of 1,000 mg/l is reached, gas production will remain high.

To prevent a drop in pH caused by an excess of acid, alkaline material such as lime or sodium hydroxide may be added to neutralize the excess acids. The continued use of such neutralizers can cause a process failure because of an ion toxicity factor (Na and Ca ions). Therefore, the actual cause of high volatile acids concentrations must be ascertained and corrected for a successful operation.

ANAEROBIC DIGESTION PROCESS

6-3



FAILURE OF STEP 2 WHILE STEP 1 CONTINUES CREATES AN EXCESS OF ACIDS REDUCING PH AND FINALLY CAUSING TOTAL PROCESS FAILURE.

FIGURE 6-1

CRITICAL FACTORS IN SLUDGE DIGESTION

The success of a digester operation and the causes of process failure depend on the following critical factors:

1. **Quantity of sludge and digester sizing** - overloading or drastic rapid changes in the rate of loading can cause process failure
2. **Quality of Sludge** - toxic materials such as metal ions can cause a process failure
3. **Temperature** - failure in the operation can be caused by a drop in temperature
4. **Mixing** - enough space must be provided in the tank for proper mixing

Quantity of Sludge and Digester Sizing

The quantity of raw sludge will depend upon:

1. The amount and type of solids in the sewage
2. The removal of solids by the sewage treatment process
3. Any change in the amount of solids produced by the treatment processes
4. The concentration of solids in the sludge to be added to the digestion tanks

Normally, the suspended solids in a domestic sewage average 0.20 pounds per capita per day. Allowances can be made for industrial waste loadings and figures are available for that purpose.

The removal of suspended solids in the sewage treatment plant varies with the type of sewage treatment and the efficiency of the process as follows:

TABLE 6-1 PERCENT REMOVAL OF SUSPENDED SOLIDS

	<u>Removal Percent</u>
Primary Settling	40-60
High-Rate Trickling Filter	75-85
Conventional Activated Sludge	85-90

The treatment process may increase the amount of solids by conversion of dissolved and colloidal material to settleable solids. Biological processes may reduce the amount of volatile solids by aerobic digestion in trickling filter and activated sludge units.

TABLE 6-2 TEN-STATE STANDARDS OF DIGESTER SIZING

	<u>Cu. Ft. /Capita</u>	
	<u>Heated</u>	<u>Unheated</u>
Imhoff tanks	--	3 - 4
Primary	2 - 3	4 - 6
Primary + high rate filter	4 - 5	8 - 10
Activated Sludge	4 - 6	8 - 12

Lower digester temperatures require greater volume allowance in the design.

Table 6-2, which is taken from the Ten-State Standards, gives a simple method of evaluating the loading in cu.ft. per capita of solids directed to a digester. Any drastic change in population and/or the addition of industries requiring water for their process (called "wet" industries) should signal possible problems because of increased loading.

Another loading criteria put forth in the Ten-State Standards, 2 to 3 lbs of solids per month per cu.ft. of digester volume provides space for sludge storage, and supernatant separation, as well as allowing some capacity for overload and a scum blanket.

When only the active digestion volume is considered, new design criteria permit a loading factor of 8 or more pounds of solids each month per cubic foot of digester capacity. The 8 pounds loading factor corresponds to a ten-day retention period for a sludge of 5% concentration. When using this criteria, only the first mixed-stage of the digestion process is considered. Additional capacity must be added for other factors, such as sludge storage, supernatant separation and overloading.

If the digestion process is compressed into too short a time period, part of the active phase of the process will be transferred to the second stage digestion unit. This will cause supernatant selection and scum blanket problems. Often the second stage digester is not equipped with mixing devices required to control blanket formation.

In smaller installations, the digestion concentrating and storage functions must be effected in one tank. This type of installation is difficult to operate and seldom can all the necessary functions be carried out as effectively as desired. In any given digester installation there is a limiting loading rate. Any increase in loading due to the development of new industries and/or residential subdivisions should be noted. Any drastic change in loading rate over a short period of time should also be noted. Even if the system is sized to handle a much higher loading rate, the bacteria in the process must have the necessary time to develop a more active culture.

SINGLE STAGE DIGESTER

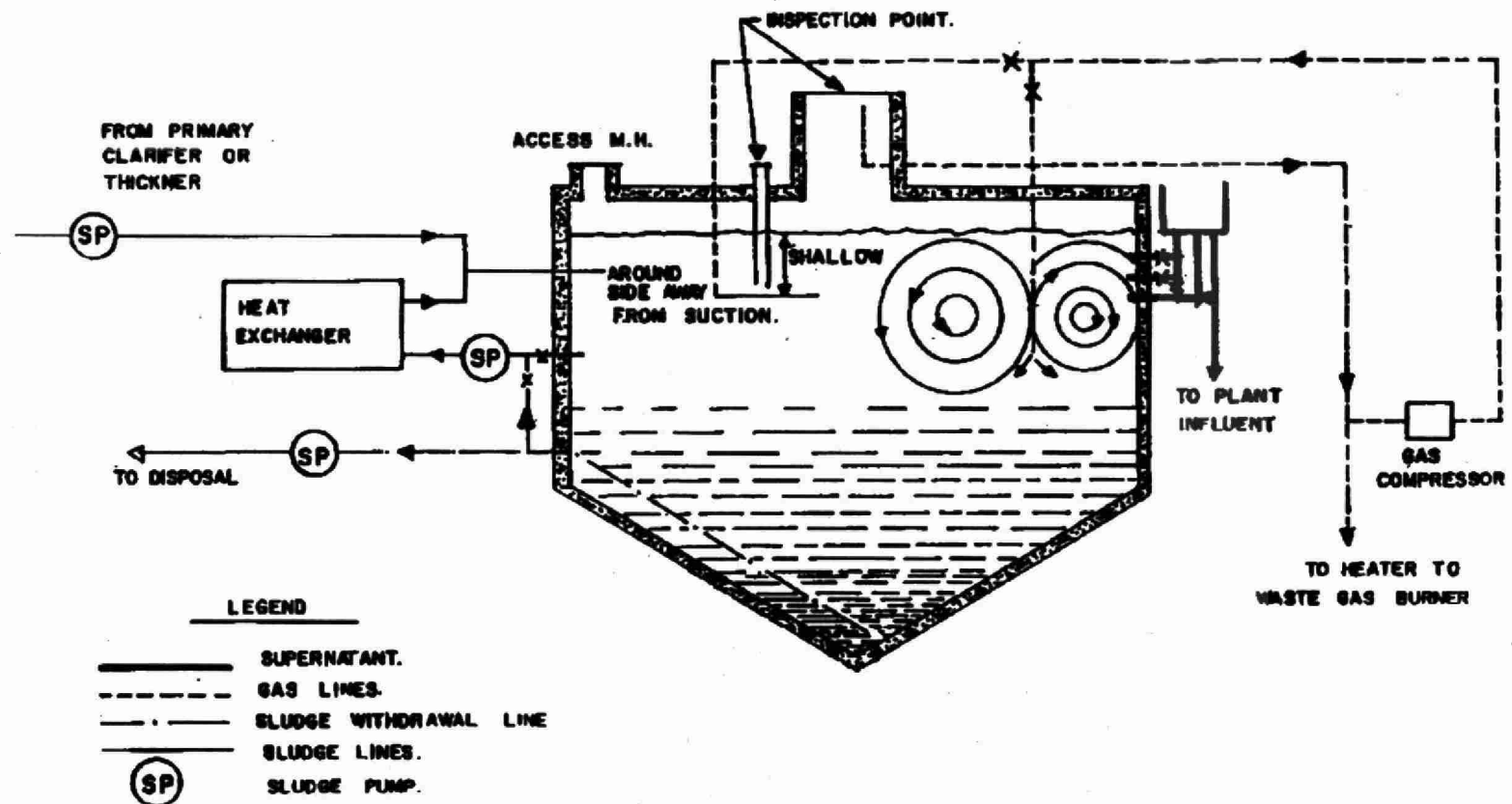


FIGURE 6-2

Quality of Sludge

1. Toxic Wastes

The presence of even trace quantities of heavy metals such as copper can create toxic conditions affecting the rate of digestion. For example, a copper level of 0.5 mg/l in the plant influent can accumulate to a concentration of 125 mg/l in the sludge directed to the digester. While a soluble copper level of 100 mg/l would completely halt the process, part of the copper may be in an insoluble form. This would permit the process to continue operating, but at a reduced level of activity depending on the concentration actually in a soluble form. Other toxic wastes which can prove to be a problem to the digestion process include chrome and nickel.

2. Grease or Oil

Greases or oils can both overload a system and reduce the active digestion volume by creating an oil or scum blanket. While the additional loading may be a factor, the character of the wastes may also prove to be a problem.

Temperature

The digestion process can be effected in the mesophyllic range (10° to 38°C) or the thermophilic range (38° to 60°C). In the colder Canadian climate, the unheated digested temperature may drop to 7°C, at which temperature bacterial activity is very low, so all installations should be equipped with heating devices. Heating can be done by outside circulation of sludge through a heat exchanger or by heating coils in the digester itself. Generally, only the first stage digester in a two-stage operation is heated.

The most favourable temperature for sludge digestion (mainly domestic) is 32°C. Lower temperatures may be used depending on the digester capacity available but some margin of safety should be maintained.

In an underloaded system the required temperature may be calculated by assuming that no digestion takes place at 10°C and a maximum rate of digestion at 32°C. A straight line is drawn to connect the two points to enable the determination of the efficiency of the process; for example, at 27°C the process could be considered to be 75% effective. In calculating temperature requirements include a safety factor to handle overloading and possible furnace breakdown.

When using internal hot water coils for heating, the water feed temperature should be maintained below 54°C, a high temperature will encrust the coils with a sludge cake. Excess water makeup requirements will indicate coil leakage and a smaller than normal temperature drop in the circulation coil water may indicate the formation of an insulation sludge layer on the coils. The use of internal heat exchange coils for digester heating is not recommended on any except small installations.

External Heat Exchangers are preferred because of accessibility for maintenance. These units also provide some mixing and at times the raw sludge feed is directed to the recirculation line to be actively mixed with the circulating "seed" sludge. In a system equipped with good internal mixing this point is to some extent unnecessary.

Mixing

The objectives of mixing or recirculation are:

1. Uniform transfer of heat to entire mass
2. Intimate mixing of raw sludge with seed sludge mass
3. Prevention of dead areas and scum blankets

Many systems have been devised for carrying out the above functions. The most satisfactory results are obtained with digester gas recirculation units or internal mechanical mixers. When these facilities are not available, some mixing is obtained by recirculating digester contents using external pumps. Directing the recirculated sludge to the top of the scum blanket may assist in controlling a scum blanket build-up.

Mechanical mixers can be operated using a timing cycle to attain the required results. In no case should the timing cycle be set with the economic use of power as the only criteria. In an underloaded digester, the mixing units are only operated to prevent the formation of a scum blanket. The draft tube level may be varied to obtain the best results.

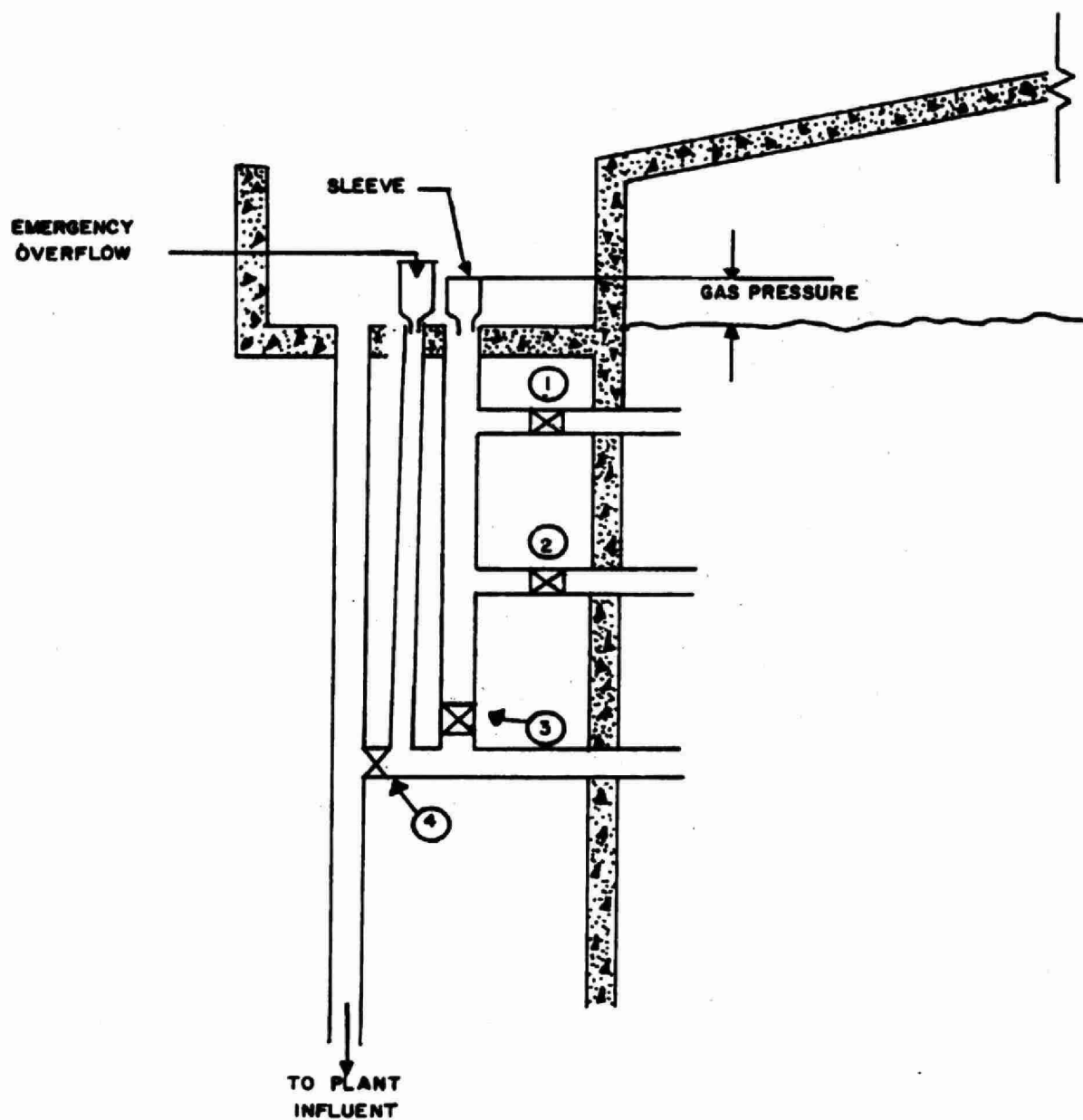
The operation of mixers in a single stage digester to provide adequate scum blanket control while obtaining a good supernatant and a concentrated sludge is a problem. Mixing must be discontinued when the supernatant is withdrawn. Therefore, single stage units are to be discouraged.

Where mixing facilities are not provided, alternate means must be developed to remove the scum blanket on a regular basis. Compressed air may be used. For example, a 125 cfm compressor may be used to supply air to mix the contents of the digester and break down the blanket. This should be done at least twice a year and a safety officer should be on hand to ensure that all necessary precautions are taken to prevent a fire or an explosion.

When air mixing is under way the compressor should be located away from the open top of the digester; remove as many of the digester top covers as possible; do not knock steel surfaces together; use non-sparking tools; SMOKING should NOT be permitted in the plant area; and the plant gates should be closed to outsiders. The air may be discharged through a one-inch steel pipe (20 feet long) which may be inserted at different points through openings in the top, or the air may be directed through a bottom withdrawal line. It is usually best to remove at least some of the settled solids soon after the mixing is stopped. In difficult cases a new blanket will again form requiring a repeat of the mixing cycle.

With inadequate mixing, a foaming problem may develop. This is caused when a scum blanket commences to digest, thus creating gas. With the blanket being firm the gas bubbles create a foaming condition. This foam may plug gas lines and overflow pipes. The solution to foaming is to reduce the load on the digester and thoroughly mix the digester contents to eliminate the scum blanket. At the same time dilution, pH control, etc. may be required to prevent process failure. This is because a large quantity of raw or partly digested sludge is added to what may be an already over-loaded system.

FIGURE 6-3



SUPERNATANT SELECTOR

Gas Production

A gas production of 15 cubic feet per pound of organic solids destroyed can be expected when the digester is operating normally. The gas will contain 65 to 70% methane and 25 to 30% carbon dioxide. During start-up and at the time of process failure, the methane percentage will be greatly reduced. The gas yield from an activated sludge plant can be approximately 1.0 cu. ft. per day per capita. In an average digestion process, approximately 33% of the total solids and 50% of the volatile solids in the raw sludge are reduced by the process. In more volatile sludges the percentage will, of course, be higher.

The quality of gas may be determined by flame colour; also, poor quality gas (low methane content) will not burn in more complex heating equipment. These factors along with daily checks on the quantity of gas produced will assist in pinpointing process problems.

ANAEROBIC DIGESTER START-UP

The following basic procedures are used for anaerobic digester start-up:

1. All construction should be completed before start-up. Alterations and repairs of internal parts are difficult to make once the digester is operating.
2. Fill all lines and tank with water. Raw sewage may be used. Do not use raw sludge as it would overload the process.
3. Add seed material if available. Supernatant or settled sludge from an operating digester is the only product which will be effective.
4. Heat tank contents to 90 to 95°F and maintain at that temperature.

5. Add raw sludge at a rate of .01 pound of solids per cubic foot of digester volume per day for an unseeded digester and a somewhat higher rate, depending on the amount of active material provided, for a well seeded digester. The loading on a high rate process can be .25 pounds of solids per cubic foot per day. The 0.1 pounds of solids per cubic foot per day is equal to 1,000 gallons of 5 percent sludge to a 50,000 cubic foot capacity digester.
6. Using available mixing facilities, circulate the digester contents and maintain the temperature.
7. Check the process daily by determining the volatile acids and pH. As the volatile acids test is a complex test, it may not be possible to do it as often as desired. As the process proceeds the quality of the gas may be checked if the gas testing equipment is available. Also, the sludge alkalinity may be determined. Lime may be added to control pH but, if the volatile acids approaches 2,000 mg/l, the sludge feed is reduced or stopped as required.

NOTE: Excess lime may inhibit the process.

8. Gradually increase raw solids loading on the basis of favourable trends. The loading must not be increased with volatile acids levels above 1,000 mg/l.

SINGLE STAGE DIGESTION OPERATION

General

Single stage digester operation is covered under four headings:

1. Loading
2. Process Criteria - Mixing, Temperature, Testing
3. Supernatant Selection
4. Digested Sludge Removal

Loading

Ideal conditions would be met if the raw sludge could be pumped continuously to the digester. For various reasons continuous loading is not possible. Small plants receiving eight hours per day of operator supervision may load the digester three times a day, say at eight in the morning, 12 noon, and four in the afternoon. Where automatic pumping facilities are provided the other extreme may be reached with loading being effected once each hour. Where supervision is provided on a 24-hour basis, manual control may dictate six to eight pumping cycles per day. Excess water will be directed to the digester if too many pumping cycles are provided. When raw sludge must be pumped for some distance, to the digester, the sludge line must be filled with dilute sludge before the pump is stopped. The next pumping cycle will direct the dilute sludge to the digester.

In a single stage operation the raw sludge is directed to the top half of the digester. As indicated in the flow diagram appended as Figure 6-2, the raw sludge may be mixed with seed sludge leaving the heat exchanger.

Process Criteria

To maintain the process, two main operating criteria must be met:

1. Mixing

Sufficient mixing must be afforded to bring the raw sludge in contact with seed material and also to sludge in contact with seed material and also to maintain sufficient area free for the digestion process. Where mechanical or gas recirculation equipment is not available a careful check must be kept on the process to ensure that a foaming condition is not created or that the reaction space left does not become too small. In a single stage unit, mixing facilities, if any, are designed only to mix the material in the top half of the tank. In practice such a design is near impossible. Thus it is difficult to obtain a concentrated sludge from a single stage digester operation. An improper mixing program could cause a process failure. The active volume available for the digestion process can be greatly reduced by the formation of a scum blanket and sludge banks. Foaming can occur when the scum blanket begins to digest, but may be partly controlled by the use of compressed air to mix the tank contents. When using air for mixing, great care must be taken to ensure that the explosive air-gas mixture is not ignited. This control measure may be required two or three times a year depending on need. Be careful when using air to mix the digester contents. Obtain the services of a safety officer. Forbid smoking in plant area, use rubber footwear, using no-sparking tools and do not bang pipe so as to cause a spark at digester openings. Also, open as many manholes as possible for ventilation.

2. Temperature

The second process criteria that must be considered is temperature. The ideal operating temperature for mesophyllic digestion is between 32-35°C. A lower temperature may be used if excess digester capacity is available.

3. Tests and Records

To maintain a check on the process, various tests and records are required. The number of tests required or that can be economically performed at a plant will greatly depend on the equipment available and the size of the plant. Also where good mixing is afforded the chance of process failure is less; and therefore fewer tests would be required. A few of the tests, **listed in order of importance**, are as follows:

- a) volatile acids
- b) temperature
- c) scum blanket depth
- d) supernatant suspended solids
- e) pH
- f) alkalinity
- g) gas compositions
- h) raw and treated sludge composition volatile and total solids

Records can also be kept of:

- sludge directed to digester
- sludge removed from digester
- quantity of gas
- mixer operating schedule

Supernatant Selection

It is difficult to obtain a good supernatant from a single stage digester. Nevertheless, an attempt should be made to remove excess liquid. Where mechanical mixing is practised, the mixing devices are shut off for a period of time before the supernatant is withdrawn. Experience will show the quiescent period required to obtain a good supernatant.

When a variable level supernatant selection is provided the supernatant is removed via the line proving to be most satisfactory. An example of a supernatant selector system is appended as Figure 6-3. Withdrawal control is maintained in simpler installations by a sleeve height adjustment. Other installations use valves to control the withdrawal process. In all installations a safety over-flow should be kept open at all times. The suspended solids test is used to check on the efficiency of the withdrawal process. The actual test can be determined using a centrifuge for quick results, and the standard suspended solids test where complete laboratory equipment is available. The raw sludge directed to the digester may have a suspended solids concentration of 30,000 to 60,000 mg/l. Therefore, the supernatant suspended solids concentration should not be allowed to approach plant operation. A suspended solids concentration of 1,000 to 3,000 might be considered permissible with the ideal level being below 500 mg/l.

Digested Sludge Removal

The accumulated sludge should be removed as frequently as possible. It will be difficult to obtain a concentrated sludge from a single stage operation. A 3% to 4% sludge may be considered good for the digested sludge obtained from an activated sludge plant utilizing a single stage digestion process.

When the gas is utilized from a fixed cover operation, the digested sludge is best removed when the raw sludge is being pumped. This practice will assist in maintaining the gas pressure.

Bottom withdrawal line and depth samples are tested to control the sludge withdrawal process. The total and volatile solids tests are two criteria used to evaluate the stability of the sludge and its concentration.

TWO STAGE DIGESTION

General

Two stage digestion is covered under five headings:

1. Loading
2. Process Criteria
3. Sludge Transfer
4. Supernatant Selection
5. Digested Sludge Removal

Loading

When high rate complete mixing is practised the raw sludge may be directed to any point in the first stage tank. Otherwise the loading procedure is similar to that used for the single stage operation. A good two stage design will allow the use of either tank for the first stage or heated unit. An example of a two stage digester flow diagram is given as appended Figure 6-4.

Process Criteria

1. Mixing

Where mixing devices are available they are operated to control scum blankets and inactive dead spaces. Most of the mixing is affected in the first stage tanks. Often mixing units are not installed in the second stage tank. The mixing devices may be operated either full or part time. When part time operation is desired the cycle is set up in relation to tests and observations of scum blanket formation and not on power saving. In some operations the mixers may only be used a few hours a day. An improper mixing program could cause a process failure. The active volume available for the digestion process can be greatly reduced by the formation of a scum blanket and sludge banks. Foaming can occur when the scum blanket begins to digest. The scum blanket may be partly controlled by the use of compressed air to mix the tank contents. When using air for mixing great care must be taken to ensure that the explosive air-gas mixture is not ignited. This control measure may be required two or three times a year depending on need. Be careful when using air to mix the digester contents. Obtain the services of a safety officer. Forbid smoking in plant area, use rubber footwear, use no-sparking tools and do not bang pipe so as to cause a spark at digester openings. Also, open as many manholes as possible for ventilation.

2. Temperature

Heating units are used to heat the contents of the first stage digestion tank. Optimum mesophyllic digestion is carried out at between 32°C and 35°C. However, lower temperatures may be used where excess digester capacity is available. The maintained temperature should be such as to provide some safety factor.

Sludge Transfer

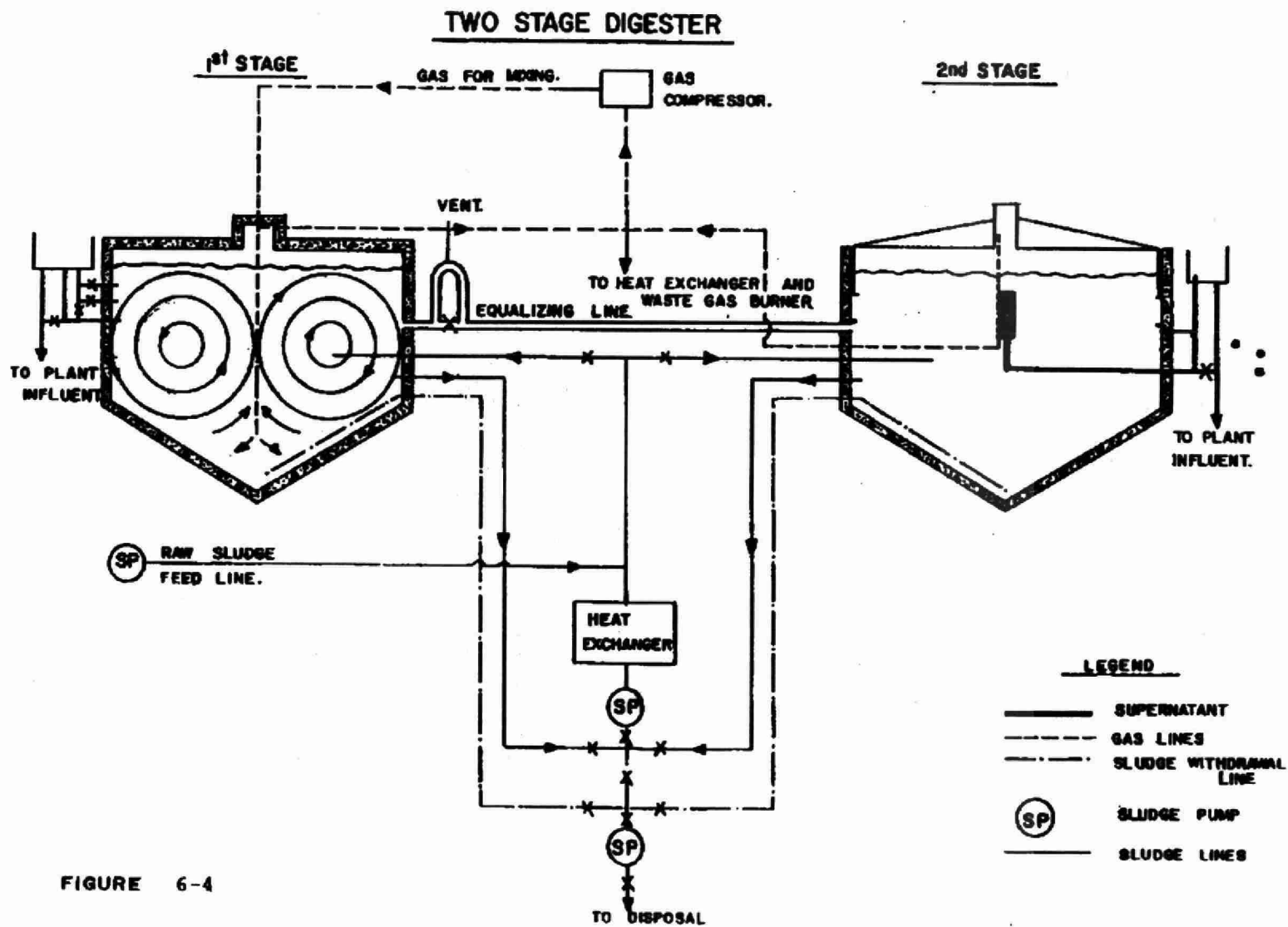
Sludge can be transferred from the first stage digester by a number of means, three of which are as follows:

1. Automatic transfer may be effected using an equalizing line, as shown on Figure 6-4.
2. Sludge may be transferred using the heat exchange unit recirculating line.
3. Bottom sludge may be pumped to the stage unit.

The transfer program should be set up to delay the removal of solids from the first stage unit. If possible, top material is transferred when the mixing devices are off. Nevertheless, frequent transfers at least once a week, must be made from the bottom of the first stage tanks. If this is not done the bottom withdrawal line will plug with grit and solids.

Supernatant Selection

The supernatant is obtained from the second stage digester. The supernatant can be selected automatically when a sludge transfer takes place or as an operating procedure when the plant can best receive the extra BOD loading. The type of selectors provided will of necessity partly dictate the program to be chosen.



Digested Sludge Removal

In a fixed cover installation the sludge must be removed in small batches. If this is not done the gas pressure will not be maintained.

When at least one floating cover is provided the sludge settled in the second stage unit may be removed as convenience requires; large withdrawals will not cause process failure or a loss of gas pressure.

Sludge samples should be collected as indicated for the single stage operation. A two stage operation will provide a more concentrated sludge.

THE AEROBIC DIGESTION PROCESS

General

The aerobic digestion process is an extension of the extended aeration process where the volatile material in the wastes is destroyed to a reasonable maximum with up to a 45% destruction of volatile solids. The aerobic digester is a separate operation in which concentrated sludge, having 3-6% Mixed Liquor Suspended Solids is processed. The decomposition of solids and regrowth of organisms is maintained until the available energy in active cells and the storage of waste materials are sufficiently low and stable enough for disposal.

CRITICAL FACTORS IN PROCESS

The aerobic digestion system is simple to operate and maintain when compared to the anaerobic digestion process. While the operator may have little control over the discussed design factors, he should be aware of system limitations if he is to effectively manage the system he is responsible for and encourage improvements.

The most critical factors include:

1. Air supply
2. Volume of system
3. Tank insulation

Air Supply

An air supply of 20 cu. ft/min. per 1,000 cu. ft. of digestion tank volume was originally suggested for aerobic digestion. This level of air feed, however, has not proven to be effective in keeping solids in suspension and maintaining a 1 mg/l oxygen level in the digesters. It is now suggested that the air supply should approach 50 cu. ft/min. per 1,000 cu. ft. of tank volume. In a conventional activated sludge plant, this air supply would be nearly twice the amount of air required in the aeration tanks.

Volume of System

The system is sized to maintain a minimum sludge age of 45 days. If complete stabilization is desired, the total sludge age could be as high as 120 days. In using the 120 day criteria the sludge age in the regular plant itself may be added to the sludge age of the aerobic digesters. An aerobic digester system having a sludge age design factor of 45 days would have a tank volume equal to the volume of the conventional aeration tanks sized to provide 8-hour detention. Since the MLSS may be maintained at a 3-6% level in the second stage of a two-stage system a small volume is possible with the two-staged unit.

Tank Insulation

In the colder Canadian climate, steps should be taken to retain the heat in the aeration tanks. For this reason, open steel tanks built above ground are not recommended. To reduce heat loss, a common wall construction with existing tanks in the plant and earth filling around the remaining walls is recommended. Additionally, long above-ground air pipes should be insulated.

OPERATION AEROBIC DIGESTER SYSTEM

Operating procedures for the aerobic digester system will be considered as follows:

1. System start up
2. Sludge feed program
3. Supernatant control
4. Transfer program
5. Processed sludge removal
6. Air control and records
7. Scum control

System Start-Up

Fill the first aerobic digester tank within three feet of the top with water (use primary or plant effluent or clear water, not sludge). Add seed activated sludge from return sludge flow. Pump raw sludge from primary. Maintain the dissolved oxygen level at 1.0 mg/l (or more).

Each day shut off the air system to allow the solids to settle; decant the supernatant to the plant influent. Continue to pump in sludge from the plant. Excess activated sludge should be wasted to the primary clarifier two hours before pumping is under-taken (this directs fresh activated sludge to digester). Where there is no primary clarifier, the excess sludge is wasted directly to the digester.

When solids have reached a MLSS level of 10,000 to 15,000 mg/l, the sludge settles to approximately 50% of tank volume. Fill the second stage aerobic digester tank to within three feet of top with primary or secondary effluent, then transfer sludge from the bottom of the first stage digester to the second stage tank. Decant the supernatant as required to maintain capacity for additional loading.

Sludge Feed

Pump sludge to the first stage digester according to the established plant program. If the plant has a primary clarifier, the waste MLSS should be directed to the primary clarifier two hours before the sludge pumping cycle begins. Sludge cannot be pumped when the digester is in the supernatant removal phase. Also, a plant not equipped with a primary clarifier must pump excess return activated sludge directly to the digester.

Supernatant Control

Shut down the air supply to allow the MLSS to settle. The time required will depend on the settleability of the solids. Then draw off supernatant from a point below the surface. The shut-down time should be short to eliminate possible problems.

Transfer Program (2 and 3 stage system)

Sludge is concentrated and transferred as required from the bottom of the first stage unit to the second stage unit. This transfer is not necessarily done each day. Remove sufficient supernatant from the second stage tank to allow the transfer to proceed. In a three-stage system, the first stage air supply is seldom shut down. Therefore, the supernatant is only removed from the final two stages.

Processed Sludge Removal

The processed sludge is removed from the bottom of the final stage for land disposal with tank trucks or it is directed to sand beds or sludge lagoons in isolated small plant operations.

Air Control

Sufficient air must be delivered to keep solids in suspension and a minimum oxygen level of 1.0 mg/l in all tanks.

Scum Control

Excess scum should be removed manually from the surface of the tanks on a regular basis.

Records

Records can be kept of sludge directed to the system and sludge removal. A centrifuge should be used to determine sludge concentrations in the raw feed, in each tank, the digested sludge and the supernatant. Laboratory tests, mixed liquor suspended solids (MLSS) and volatile solids should be obtained as required to check the process operation.

SUBJECT:

TOPIC: 7

**SEWAGE TREATMENT
OPERATION**

SLUDGE HANDLING METHODS

OBJECTIVES:

The trainee will be able to:

1. Define sludge and name its sources in the waste treatment process.
2. List the concentration of solids (in percent) expected in:
 - a) raw primary sludge
 - b) waste activated sludge
3. List three factors which determine the quantities of sludge produced.
4. Describe four methods used to dewater sludge.
5. List five factors that influence the selection and use of chemicals.
6. Discuss the methods of final sludge disposal.

SLUDGE HANDLING

GENERAL

What is sludge? Sludge is the residue resulting from the removal of dissolved or suspended material during the treatment of water and wastewater. Sludges are usually identified in terms of the treatment process in which they originate, e.g. raw sludges from primary sedimentation, primary sedimentation, digested sludges from aerobic and anaerobic digesters.

CONSIDERATIONS IN SLUDGE HANDLING

Sludge Concentration

Sludge concentration is defined as the reduction in moisture content of a sludge in order to decrease sludge volume while still maintaining its fluid properties. By this definition, sludge, dewatering is excluded, because the purpose of dewatering is to reduce the liquid sludge to a relatively dry cake. To a limited extent, sludge concentration occurs in most clarifier operations; however, this is not the purpose of the clarifier and the concentration of solids in sludge is best carried out in a separate unit. It must be remembered that if there is initially less water in a sludge then the disposal of this sludge will be less costly. When trying to concentrate sludge in the clarifier one must remember that most pumps are not designed to carry sludge which has total solids concentrations of greater than 10 percent. Waste activated sludges characteristically have concentrations of only 0.5 to 1 percent (%). A reduction in volume by concentrating to 3-4 percent (%) would be significant. Such sludges are quite fluid and easily pumped. Raw primary sludges normally have concentrations of 5 percent or higher.

Sludge Quantities

It is necessary to know the amount of sludge that can be produced at a sewage treatment plant for design requirements, budget requirements and for process control and efficiency. The volume of sludge that is produced is dependent on a number of factors, three of which are listed below:

1. Raw sewage strength and quantity
2. Type and degree of treatment provided
3. Type and degree of sludge treatment

The sewage strength is normally measured in terms of BOD and suspended solids concentrations. These measurements can be affected by such parameters as the type of industries on the sewage system, the degree of infiltration into sewers, and the consumption of water per capita. For a normal domestic waste, the loading on a plant can be estimated by allowing 0.17 pounds BOD and 0.20 pounds suspended solids per capita per day.

The degree of treatment that a sewage treatment provides will affect the quantity of sludge produced. The following table lists the removals expected at various types of plants.

TABLE 7-1 EXPECTED REMOVALS

TYPE OF PLANT	BOD(5)	S.S.
Primary Sedimentation	30 - 60%	50 - 60%
Single Stage Low Rate Trickling Filter	80 - 90%	80 - 90%
Conventional Activated Sludge	85 - 95%	85 - 95%

For the purpose of this topic and without considering the more exotic forms of sludge treatment, sludge is considered to be either digested or raw. The volatile solids content of the sludge can range from 60 to 85%. As a general rule, digestion provides for approximately a 40 to 60% destruction of the volatile solids but this percentage can be higher. This destruction, of course, is dependent on such factors as mixing temperature, detention time, and the initial volatile solids content of the sludge.

One should note that in a conventional activated sludge, excess (or waste) sludge is produced and must be disposed of. The quantities generated depend, in part, on a relationship between the oxygen available, the concentration of organisms and the organic load.

Sludge Withdrawal

Raw sludge withdrawal should consist of a sludge as dense as possible, preferably in the range of 5 to 7 percent total solids. The settling tank hoppers should be cleared as thoroughly as possible without drawing liquid. Sludge may be removed by hydro-static pressure in some installations or by pumping. The manner in which sludge is removed has a great effect on both the settling tank and the digester.

It is generally better to remove sludge three to four times a day and provide a more constant food supply to the organisms doing the work, than to remove all of the daily sludge accumulated at one time. If too little sludge is removed, the clarifier effluent will deteriorate. If too much is removed, the digester operation will deteriorate and extra supernatant must be treated. See Examples 1 and 2.

A constantly watery sludge would indicate that too much sludge is being pumped; eg. the sludge concentration in the digester is not allowed to increase. If a thick sludge is being pumped at the beginning of the pumping cycle and turns watery towards the end, the pumping rate is too high. In this case, the volume of sludge entering the pit or hopper is not as great as the amount being pumped out of it. Since the pumping rate is not easily adjustable, the length of the pumping cycle should be decreased and the pumping frequency increased. At the primary treatment plant, a general guide would be to pump approximately 13.5 m₃ of sludge per 4500 m₃ of raw sewage treated; the exact amount to be pumped will depend on local conditions. Gas bubbles and pads of black sludge on the surface are an indication that the settled sludge is becoming anaerobic. In this case, the frequency and the amount pumped should be increased to remove the sludge more quickly and thus prevent these conditions. If the sludge is particularly difficult to pump even though there is little sludge in the tank, check the volatile solids. If they are less than 50%, this probably indicates that an excessive amount of grit has found its way into the clarifier. A more frequent cleaning of the grit facilities should rectify this.

EXAMPLE 1

GALLONS OF RAW SLUDGE TO BE REMOVED (Figure 7-1)

(Based on the Following Parameters)

1. 5% Total Solids
2. 60% Removal of Suspended Solids

Curve A: influent s.s. - 250 mg/L
(effluent s.s. - 100 mg/L)

Curve B: influent s.s. - 200 mg/L
(effluent s.s. - 80 mg/L)

Curve C: influent s.s. - 150 mg/L
(effluent s.s. - 60 mg/L)

Curve D: See NOTE below

The operator should now compare his sludge pump capacity with the amount to be removed and arrive at a figure for timing his sludge removal to prevent removal difficulties noted elsewhere.

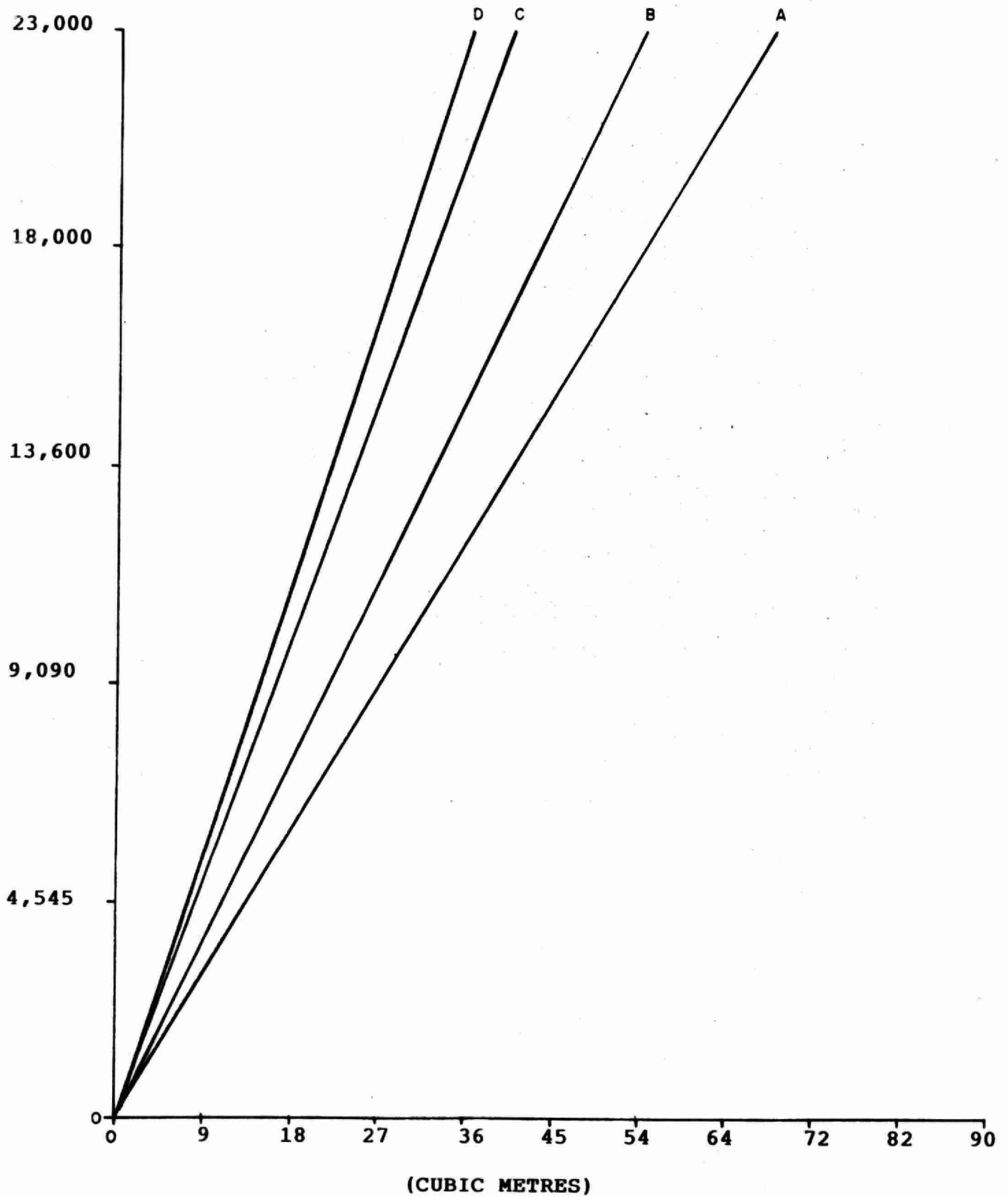
NOTE: For actual removals, the spacing of the curves on the graph change as follows (see Curve D Figure 7-1):

Assume inlet s.s. - 200 mg/L (measured in lab)

Assume outlet s.s. - 120 mg/L (measured in lab)

Therefore removal is 40% = 80 mg/L

PRIMARY SLUDGE REMOVAL



CONDITIONING OF SLUDGES

Use of Chemicals

Prior to being dewatered, most sludges must be pre- conditioned or flocculated using chemicals. When flocculation occurs, the solid particles are agglomerated in the liquid and The liquid is withdrawn by vacuum while the solids are deposited on the filter media.

The chemicals used for flocculation vary; however, the most commonly used chemicals are polyelectrolyte (polymers), ferric chloride and lime. The amount and type of chemical used will depend on the sludge to be filtered. Several factors influence the chemical demand:

1. Sludge Concentration
2. Type of Sludge
3. Size, Shape, Density and Charge of Solid Particle
4. Compressibility of Solid Particles
5. Viscosity of Filtrate
6. Alkalinity (Chemical Composition)

Sludge concentration is a critical factor. Increasing the solids concentration will increase the filter yield. The more concentrated the sludge, the less filtrate has to be removed per pound of filter cake deposited. Concentration also lessens the liquid demand, and, hence, lowers the amount of chemical coagulation required. Since activated sludge is thin (usually less than 1% total solids) the chemical demand for this type will be much higher than a concentrated primary sludge (6-10% total solids).

The second most important factor is alkalinity. If alkalinity is reduced, the chemical demands are reduced. One process which reduces alkalinity is elutriation.

Basically, elutriation is a solids washing process. An elutriated sludge is one that has had the alkalinity of its water reduced by dilution, sedimentation, and decantation in water of much lower alkalinity.

One important point that must be noted is that no two sludges have the same characteristics. If for some reason one particular type of chemical works well in one operation, it will not necessarily work for another.

Wet Air Oxidation

The Wet Air Oxidation process converts the sewage sludge structure to one that is easily dewatered. Hence, the sludge solids may be separated from the liquid portion of the sludge by settling in Decant Tanks and then dewatered to 65% moisture content on Vacuum Filters. The resulting filter cake is sterile and may be disposed of on land or by other convenient methods.

In the Wet Air Oxidation process, raw primary, waste activated and digested sludges or combinations thereof are heated with air to a reaction temperature of approximately 180°C for 15 minutes. The pressure of the incoming sludge is increased by the use of high pressure sludge pumps and high pressure air injected into the system immediately down-stream of the high pressure sludge pumps. The pressure in the system is increased as required to approximately 320 p.s.i.g., to raise the boiling point of the water in the sludges in order that oxidation may occur in the presence of water. High pressure steam is injected to sustain the temperature during the reaction time. With the addition of air and adequate temperature and pressure, oxidation of the organic material takes place.

The oxidation results in the formation of the following by-products:

1. Carbon dioxide
2. Water vapour
3. Residual water (bound water extracted from the sludge)
4. Oxidized sludge

As the mixture is discharged from the Reactor, it surrenders its heat in Heat Exchangers to the fresh incoming sludge and air mixture.

Cooled, oxidized sludge is allowed to settle in Decant Tanks for approximately one hour. The settled sludge is pumped to Vacuum Filters where free water is removed from the oxidized solids without chemical conditioning. The resulting sterile filter cake is then removed for storage and ultimate disposal. The Decant Tank supernatant and the filtrate which contain about 2000 mg/L suspended solids and 6500 mg/L BOD should be held in available storage tanks and then returned to Aeration Tanks during periods of low flow. Figure 7-2 illustrates the Wet Air Oxidation Process.

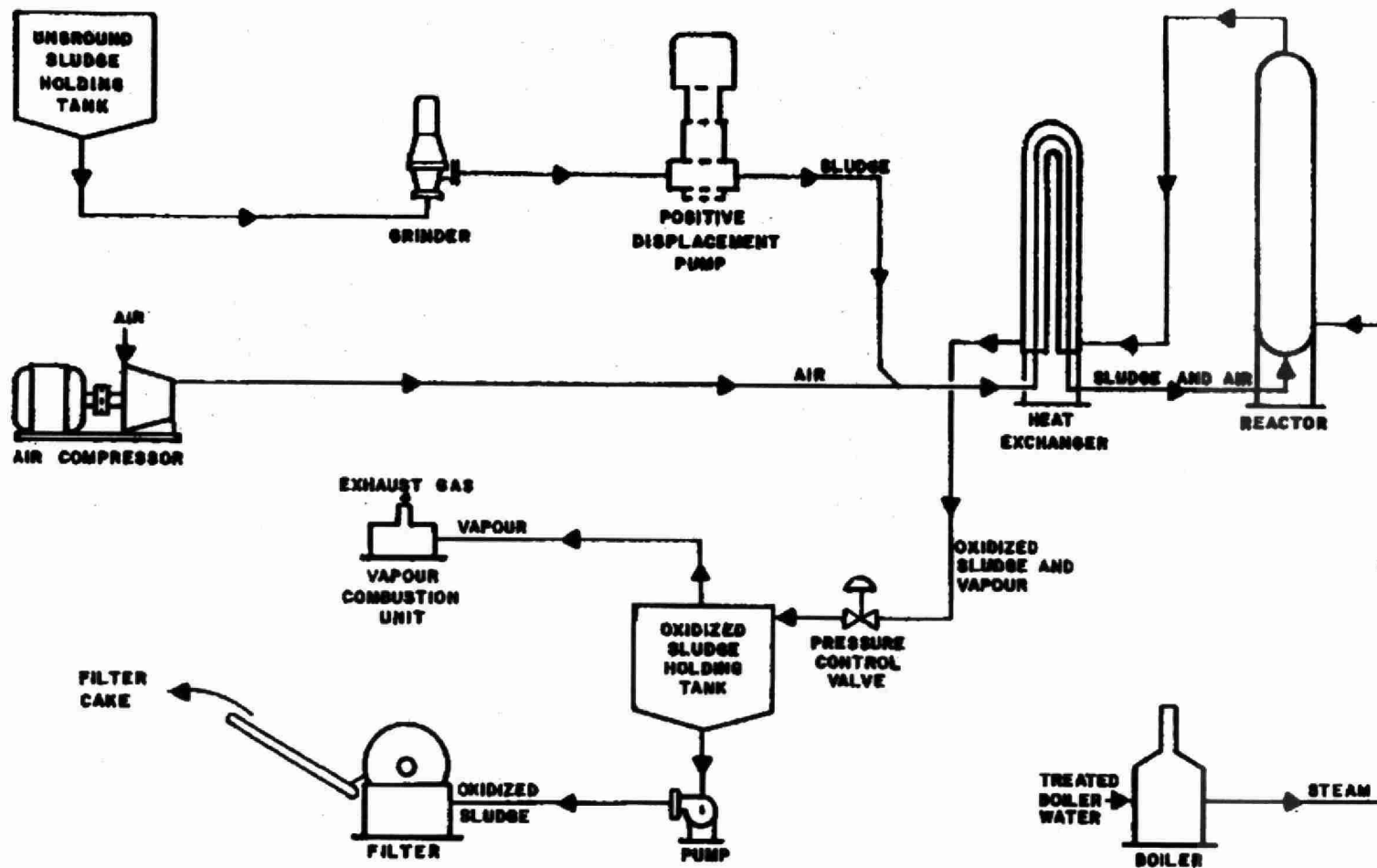
DEWATERING

At present there are several methods available to dewater sludge. These methods include:

1. Drying Beds
2. Vacuum Filtration
3. Centrifuging
4. Sludge Lagoons
5. Heat Drying

It should be noted that in the first four methods above the sludge cake must be disposed of by incineration or land disposal, whereas that from the heat drying process can be used as a soil conditioner.

**Figure 7-2 WET OXIDATION PROCESS
THERMAL SLUDGE CONDITIONING AND DEWATERING**



Drying Beds (Figure 7-3)

One of the more simple and economical methods of dewatering sludge is the use of drying beds. Although not used extensively in Ontario, approximately 2/3 of the sewage treatment plants in the United States have them. Using this method, a sludge can be dried to approximately 25 percent (%) or more dry solids during a period of several days of dry weather. The dewatered cake is usually loaded onto a truck by using a shovel or garden fork. The reason heavier, mechanical equipment is not used is because the underdrain system cannot withstand heavy loads on it. The surface area required for sludge drying beds is determined first by climatic conditions.

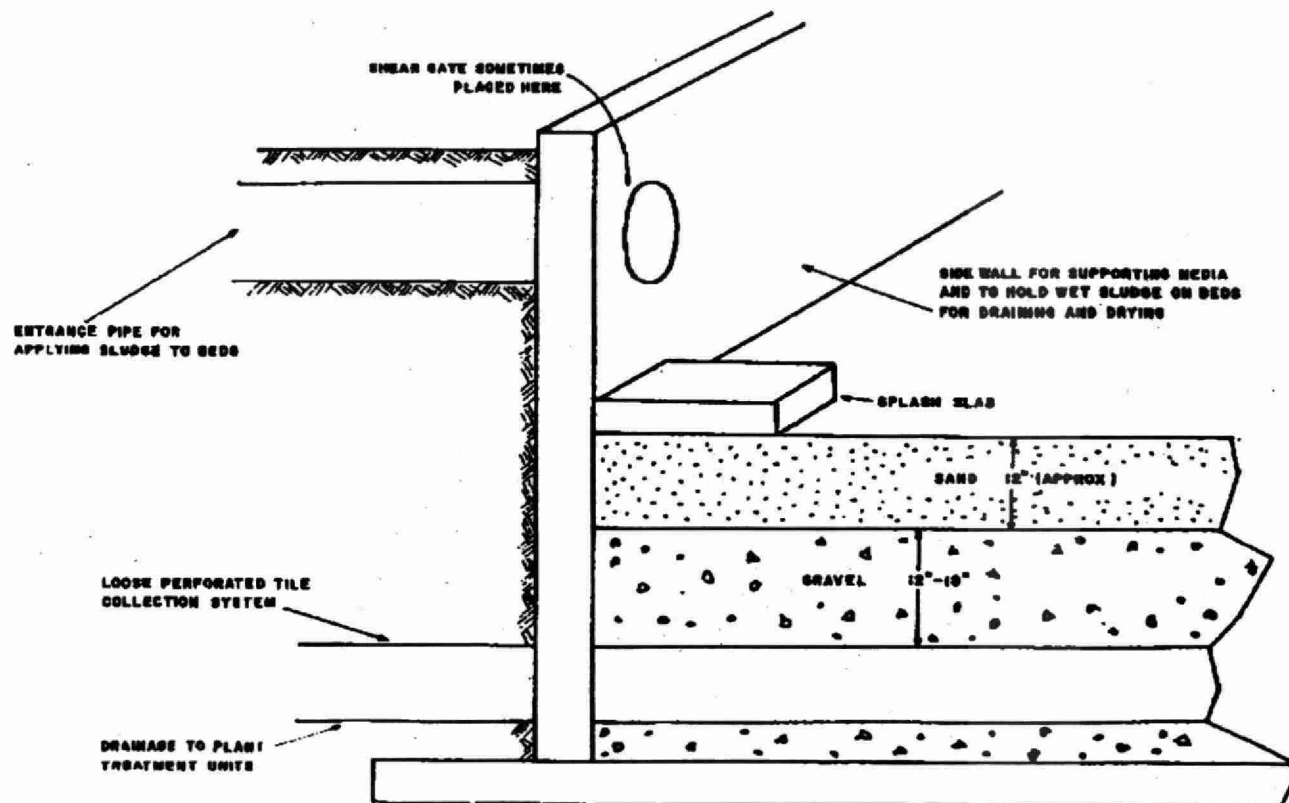
The basic principle in dewatering of sludge on sand drying beds is filtration of the water through the sand and surface evaporation. The filtration usually takes place during the first few days, but depends on the sludge characteristics and depth of sludge applied to the drying bed.

After the filtration stage is completed the sludge then dries to an equilibrium moisture content with the surrounding air. Therefore the drying does not only depend on temperature but on the relative humidity of the air and the nature of the water in the sludge. It should be noted that some water in certain types of sludge are bound for example: raw and partially digested, and therefore does not dewater easily. However, digested sludge is easily dewatered because it contains a low bound water content.

Unless the sludge drying bed is properly constructed it is of little use. Sludge drying beds normally consist of approximately 30 cm of sand over approximately 45 cm of gravel. The bed is drained by the underdrains placed in gravel about 2.7 m apart; this space will depend on sub-soil characteristics. The supernatant from the underdrain system should be returned to the primary clarifier or aeration section of the treatment plant for further treatment. Sidewalls of the beds are made of concrete, wood or earth berms. The height of the sidewalls is usually 30 cm and the sludge is usually pumped to a level of 15 to 25 cm. It should be noted that several little beds are better from an operation point of view than one large single bed. The width of the bed is flexible; however, through practice it has been found that 6 m is a good operational width. The length is usually less than 30 m. Sludge may be expected to flow approximately 30 m from a single outlet when the grade of the bed from the outlet is 1.5 m per 300 metres. Although sludge drying beds are not extensively used, usually in Ontario the ones which have been designed and operated properly have given satisfactory results.

Figure 7-3

SLUDGE DRYING BED (SCHEMATIC)



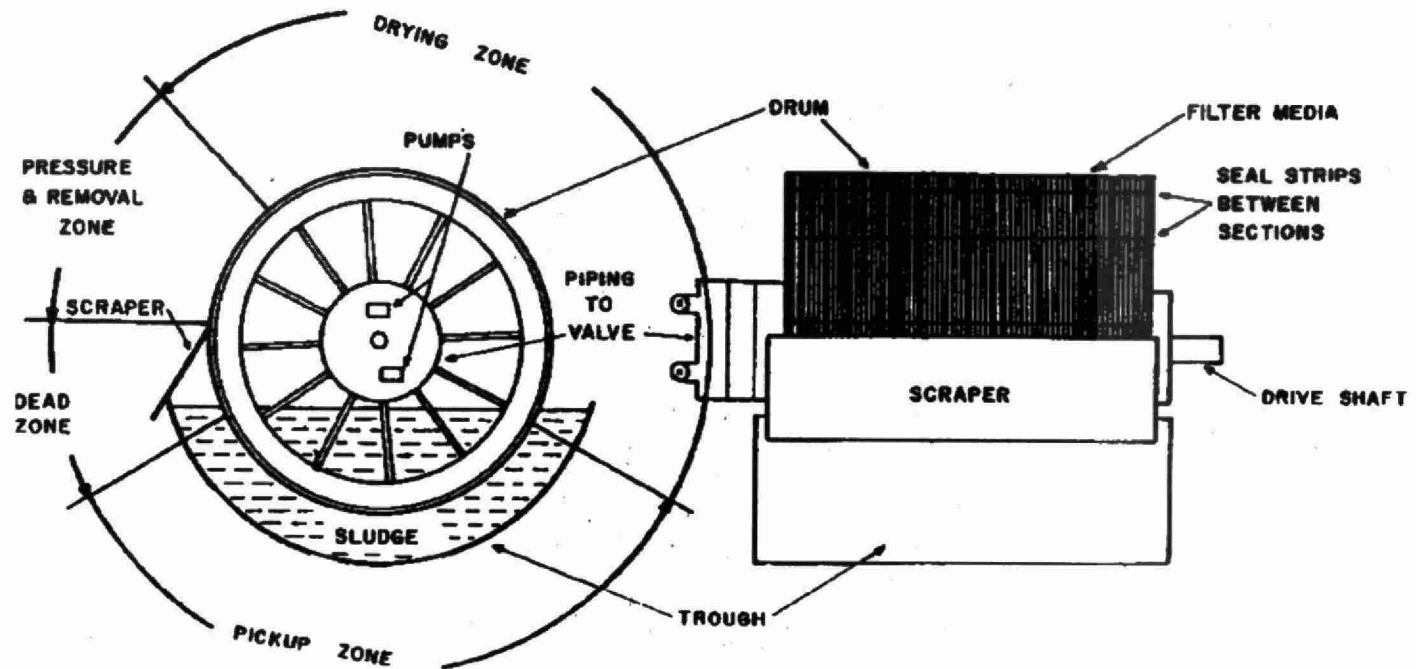
Vacuum Filtration (Figure 7-4)

Vacuum filtration is one of the most widely used types of mechanical sludge dewatering devices. Filters are adaptable to handling the various forms of raw and digested sludge. The basic process of filtration is separation of the solids from the liquid by means of a porous media which retains the solids (filter cake) and lets the liquid portion pass through (filtrate). The filter media used are of four basic types: (1) Fabric Covered Filter (cotton, wool, felt, dacron, saran, polyethylene and others); (2) String Filters (these filters use a fabric media but the sludge cake is removed from the drum by strings which pass around it); (3) Travelling Belt Filters (these consist of a stainless steel woven wire belt which serves as filter media); (4) Coil- spring Filters (two layers of coiled steel springs are placed in a corduroy fashion around the drum. As the layers leave the drum, they are separated from each other and the filter cake is lifted off and discharged).

The filtration process is accomplished by means of a horizontal drum covered with a filter media. The drum is rotated in a tank with about one quarter of the drum submerged in wet sludge. Valves and appurtenances are arranged in such a manner that as the drum rotates, a vacuum is applied on the inner side of the filter media, drawing out water from the sludge and picking up a layer of sludge on the filter media. The vacuum is continued as the drum revolves and this continuous vacuum pulls the unbound water from the sludge mat, leaving a semi-dry cake of sludge on the outer surface. The sludge cake is then scraped, blown or lifted away from the drum before it enters the sludge tank again.

Figure 7-4

SLUDGE VACUUM FILTER



The performance of the vacuum filter is measured by the rate at which dry solids are produced (pounds per hour of dry solids filtered per square foot of filter surface). These rates will vary according to the type of filter media used and type of sludge dewatered. The filtering rates for various sludges are indicated below:

Table 7-2 Filtering Rates (Imperial Measure)

Types of Sludge	Average Yield lb/sq ft/hr	Range
Primary	8	6.5 - 11.5
Primary digested	7	4.5 - 12.5
Primary digested-elutriated	7	3.2 - 13.0
Primary and Activated	4	
Primary digested and Activated	3	2.3 - 3.2
Primary digested and Activated elutriated	3.1	

Operating costs for vacuum filtration vary greatly from one installation to the next. However, when final disposal is incinerated, then the vacuum filter can be used on non-digested sludges thereby eliminating the necessity of a digester and reducing the overall capital and operating cost for the treatment plant.

Centrifuging

One of the more recently established methods of dewatering is centrifuging. There are several types of centrifuges available and all have their particular application.

A centrifuge is basically a clarifier with the sedimentation taking place under forces greater than gravity. The centrifugal force produced in the machine acts on a suspended particle in the sludge, causing it to settle through the liquid component. By either rotating the bowl at high speed or by the addition of chemicals the settling forces acting on the solid particles are increased greatly.

Several variables affect the theoretical clarifying capacity of centrifuges:

1. Particle size, shape and maximum settling rate of the smallest particle to be handled.
2. The time under which the centrifugal force is available for settling.
3. The liquid depth through which the solid particles must settle.

The foregoing gives the basic theory behind the operation of centrifuges. Although the number of installations in Canada is very limited, good operating data has been obtained.

The operation of a centrifuge at Simcoe, Ontario determined that a good centrate, one which has a suspended solids content of less than 200 mg/l, a disposal cake, some in the order of 16-25% plus or minus 5% could be obtained at an overall cost lower than the conventional methods of disposal. It also determined that manpower was not a factor.

Sludge Lagoons

Another method of dewatering sludge is sludge lagoons. This method of dewatering was widely used in Europe; however, because of the large land requirements it has fallen into disuse. The basic principles on which a lagoon operates is evaporation and supernatant withdrawal. Without both of these principles in operation the usefulness of lagoons is seriously limited.

Heat Drying

This method of volume reduction can be employed for most types of sludges - primary, secondary, raw, or digested.

Sludge is dried:

1. to reduce the volume of sludge by lowering the moisture content from 75 percent to 10 percent
2. to retain the fertilizing properties of the sludge
3. to retain and improve its soil conditioning properties
4. to destroy organisms capable of producing disease
5. to reduce odours in the sludge

Equipment includes:

1. **Rotary Kiln Dryer** - This is a cylinder set on an inclined plane with length eight to ten times its diameter. The cylinder revolves at a very slow speed (4 to 8 rpm). The sludge to be dried enters at the upper end and is carried to the discharge by gravity as the cylinder rotates. Heated gases (up to 371°C) are introduced to the cylinder and mixed with the relatively cold sludge. The exhaust gases from the drier must be oxidized at a temperature of 649 to 760°C in order to reduce serious air pollution.
2. **Flash Drier** - Consists of a cage-type mill where the sludge particles are dried almost instantly as they are removed and held in suspension in a stream of hot gases (204°C). The gas-borne sludge particles are blown to a separator where the dried sludge is trapped and removed from the moisture-laden gases.
3. **Spray Dryer** - Consists of a vertical tower down which a current of hot gases flow. Fine particles of wet sludge are sprayed into the tower and the water evaporates from the sludge particles and passes off with the gases into the atmosphere.

Dried sludge from the rotary kiln is granular and may contain larger clinker-like masses which require grinding. The waste resulting from the flash and spray dryers is a fluffy material suitable for fertilizer use.

FINAL DISPOSAL

Incineration

Incineration is a popular method of sludge disposal at very large sewage plants. It has the advantage of freedom from odours, independence of weather and in reduced volume and weight of the end product to be disposed of. There is a minimum size of treatment plant below which incineration is not considered economical since the process requires the use of expensive equipment.

Incineration is achieved by flash type incinerators, which are similar to the flash type dryers but at a temperature of approximately 871°C, and multiple-hearth furnaces where the sludge is burned to an ash.

Land Disposal by Liquid Haulage

Many municipalities are using this method of sludge disposal. It is popular where residences are located close to the plant or space is limited for lagoons or sand beds. It is a simple and economic procedure if the distance to the dump site is not too great.

Both raw and digested sludges may be spread on land where adequate aging and cultivation is affected. Where an adequate aging period is not allowed the land should not be used for crops which may be eaten raw. **At no time should either raw or digested sludge be spread on growing crops which may be consumed raw.** Unless sludges are effectively heat dried they should not be spread on active grazing land. Forage crops which have been treated with sludges not rendered innocuous by heat drying should be cured before use.

With the exception of the nitrogen and phosphorous content in undigested activated sludge, the fertilizer content in sludge is small. Therefore, the greatest percentage of sludge products are classified as soil conditioners, and not fertilizers. Nevertheless this material whether termed as fertilizer or soil conditioner, can provide valuable humus and trace elements to the soil. The three main constituents required in commercial fertilizer are nitrogen, phosphorous and potassium. Nitrogen and phosphorous are available in good percentage in sewage sludge while potassium is generally available in amounts less than 1 percent.

The type of sludge treatment as well as the nature of the raw sewage have a great bearing on the value of the resultant sludge as a soil conditioner. With respect to nitrogen content, undigested activated sludge is greatest, with digested activated sludge, raw primary sludge, and digested primary sludge following in that order.

When disposing of sludge, great care must be taken to ensure that nuisances are not created. Common sense rules must be followed to prevent obnoxious odour complaints. When a municipality receives numerous complaints regarding refuse and sludge disposal, very restrictive regulations may be enacted.

Only very isolated dumping areas should be used for raw sludge and the applied material must be ploughed in very quickly. Winter weather will prevent odours but it may be difficult to work the sludge into the soil early in the spring and obnoxious odours might develop at that time. In general, raw sludge products must be handled very carefully. It might be advisable to dispose of raw sludge at a landfill project, where daily coverage can be provided.

Digested sludge is less odorous and therefore immediate coverage is not as important. Liquid sludge can be spread evenly and thinly. Where quick drying is possible, on sandy and elevated dry land, it may be disposed of close to homes. Nevertheless, great care must be taken that obnoxious odours do not carry to residences and, furthermore, only well digested liquid sludge can be considered in this category.

Digested sludge cake must be handled more carefully. It is difficult to spread thin and therefore wet lumps of material may emit some offensive odours. If possible this material should be worked into the soil soon after spreading.

Sludge Composting

The composting of sewage sludge and municipal garbage into humus valuable as a soil conditioner and nutrient for plants is the alternative to landfill or incineration. However, the method is based on the recycling of wastes back to the soil and is therefore strongly dependent on the demand for the compost product.

Composting may be defined as the biological decomposition of organic solid wastes to a relatively stable end product.

SUBJECT:

TOPIC: 8

SEWAGE TREATMENT

CHLORINATION OPERATION

OBJECTIVES:

The trainee will be able to:

1. Name the seven (7) physical properties of chlorine.
2. Explain the main purpose for chlorination of sewage treatment plant effluents.
3. Name and explain four other uses of chlorine in sewage treatment plant operation.
4. Define:
 - a) Chlorine Dosage
 - b) Chlorine Demand
 - c) Chlorine Residual

Explain how they relate to each other.

5. Calculate the dosages of chlorine required to obtain the chlorine residual in the plant effluent.
6. List three methods used to determine chlorine residual.

CHLORINATION OF SEWAGE

PURPOSE

Chlorination means application of chlorine. The principal purpose of chlorination is disinfection of plant effluent-killing bacteria and viruses harmful to man. In the killing of the bacteria and viruses the chlorine does not do it directly but mainly by the formation of hypo-chlorous acid (free residual chlorination) which is formed when chlorine gas and water are mixed in the chlorinator and injected into the chlorine contact chamber. Chlorine is also used for:

1. The control of odours
2. The reduction of BOD
3. Aiding the activated sludge process
4. Sludge thickening

Chlorine may be applied as a gas, as a gas dissolved in water, or in the form of a hypochlorite obtained from salts such as sodium or calcium hypochlorite which, when dissolved in water, release chlorine. Chlorine gas costs much less, is not as bulky as the hypochlorite form, and is generally used in sewage treatment, unless a relatively small quantity of chlorine is required.

CHLORINE PROPERTIES

Chlorine is a poisonous greenish-yellow gas with a penetrating characteristic odour at normal temperature and pressure. It is 2½ times as heavy as air, and one of liquid chlorine equals 450 volumes of chlorine gas. It can be compressed into a liquid which has a clear amber colour. At -34°C chlorine has zero (0) vapour pressure, and at room temperature of 20°C its vapour pressure is 82 pounds per square inch. Chlorine has a high co-efficient of expansion. For example a temperature rise of 10°C (say 70°C to 21°C) will increase the liquid volume from 84% to 89% in the cylinder. Such an expansion could easily rupture a cylinder or the feed line full of liquid chlorine. This is the reason for the regulation that chlorine containers must not be filled to more than 85% of their volume, and also this has to be considered when:

1. feeding chlorine gas from a cylinder
2. dealing with a leaking cylinder

Note: For detailed procedures outlining the handling of chlorine gas cylinders refer to the Ontario Ministry of the Environment "BASIC GAS CHLORINATION WORKSHOP MANUAL".

Chlorine by itself is non-flammable and non-explosive but it will support combustion.

SUMMARY

Greenish-Yellow colour gas (poisonous)
2-1/2 times heavier than air
Amber colour liquid (when compressed)
High rate of expansion
Moderately soluble in water
Non-flammable and non-explosive
Supports combustion at high temperature

Physiological Effects

Chlorine can be detected by smell, even in very small concentrations. The least detectable amount of chlorine in the atmosphere is about 3.5 (mg/l) and when this occurs, the operator should be alerted to the potential hazards, such as leaks, or faulty equipment. At higher concentrations, chlorine will have physiological effects. The maximum amount that can be inhaled for one hour without serious effects is about four (4) mg/l. At fifteen (15) mg/l, chlorine will cause irritation of the throat; at thirty (30) mg/l, it will cause serious spells; and at forty (40) to sixty (60) mg/l, it is extremely dangerous for one-half hour exposure. A few breaths of air containing 1,000 mg/l would be lethal.

REACTION OF CHLORINE IN SEWAGE

To determine at what points as well as how much chlorine should be applied to the treatment process, the action of chlorine when added to sewage must be understood.

Chlorine is an extremely active chemical that will react with many compounds to produce many different products:

1. If chlorine is added, it will first react rapidly with reducing compounds such as hydrogen sulphide and ferrous iron. No disinfection results.
2. As more enters solution, it will react with all of the reducing compounds and organic matter present, forming chloroorganic compounds, which will have a slight disinfecting action.
3. Chlorine added in excess of that required by Steps 1 and 2 will react with ammonia and other nitrogenous compounds to produce **chloramines**.

The chlorine used by these organic and inorganic reducing substances (Steps 1 and 2) is known as the chlorine demand.

Disinfection results from that amount remaining after the chlorine demand has been satisfied. The quantity of chlorine in excess of the chlorine demand is defined as the chlorine residual.

For example: if the chlorine residual was measured to be 0.6 mg/l, then the chlorine demand could be estimated:

chlorine dosage	7.5 mg/l
chlorine residual	<u>- 0.6 mg/l</u>
chlorine demand	6.9 mg/l

To disinfect the plant effluent, sufficient chlorine must be added to satisfy the chlorine demand and leave a chlorine residual that will destroy bacteria. Disinfection of sewage has arbitrarily been defined as the addition of sufficient chlorine so that a chlorine residual of 0.5 mg/l is available for at least a contact time of 15 minutes. This has been found to give adequate disinfection. The Ministry of the Environment expects this to be maintained at all times.

The quantity of both organic and inorganic substances in sewage varies from place to place and from time to time, so the amount of chlorine to be added will also vary.

Chlorine is a surface-active agent and there is a reasonable chance that bacteria hidden within solid particles will not be killed by chlorine. For this reason, chlorine is added for disinfection purposes at a point after solids removal. Because of possible hidden bacteria within particles, chlorination cannot properly disinfect raw sewage.

CONTROL OF CHLORINATION

As mentioned, a chlorine residual of 0.5 mg/l after 15 minutes of contact is required. To ensure at least 15 minutes of contact before discharging the effluent to a receiving stream a chlorine contact chamber (see Figure 8-1) is provided. The chamber is baffled to provide total mixing of chlorine with the effluent and prevent "short circuiting".

Accurate control of the chlorine residual may be impossible, due to the great variations in flow and strength of sewage. In small plants the residual should be checked each day when the maximum flow enters the plant. This normally ensures a sufficient chlorine dosage during the rest of the day. In larger plants the dosage should be adjusted during the night when the flow and chlorine demand is much lighter.

The operator should record all chlorine residual measurements and the amount of chlorine used each day. A comparison of the dosages and residuals can then be made. Also, there will be evidence that proper disinfection of the plant effluent is being performed continuously by the operating staff.

Chlorine Dosage

The dosage of chlorine or any chemical indicates the amount being applied. It is measured as a concentration, such as the mass of chlorine applied to a certain amount of water or sewage, usually in milligrams per litre (mg/l).

Example: if a chlorinator is set to feed 94.8 kg of chlorine per 24 hours and the sewage flow is at a rate of 7.900 m³/d, the chlorine dosage would be calculated as follows:

$$\begin{aligned} (1 \text{ mg/L} &= \frac{1 \text{ kg}}{1000 \text{ m}^3}) \\ &= \frac{94.8 \text{ kg Cl}_2/\text{d}}{7.9 \times 1000 \text{ m}^3/\text{d}} \\ &= \frac{12 \text{ kg/Cl}^2}{1000 \text{ m}^3} \\ &= 12 \text{ mg/L} \end{aligned}$$

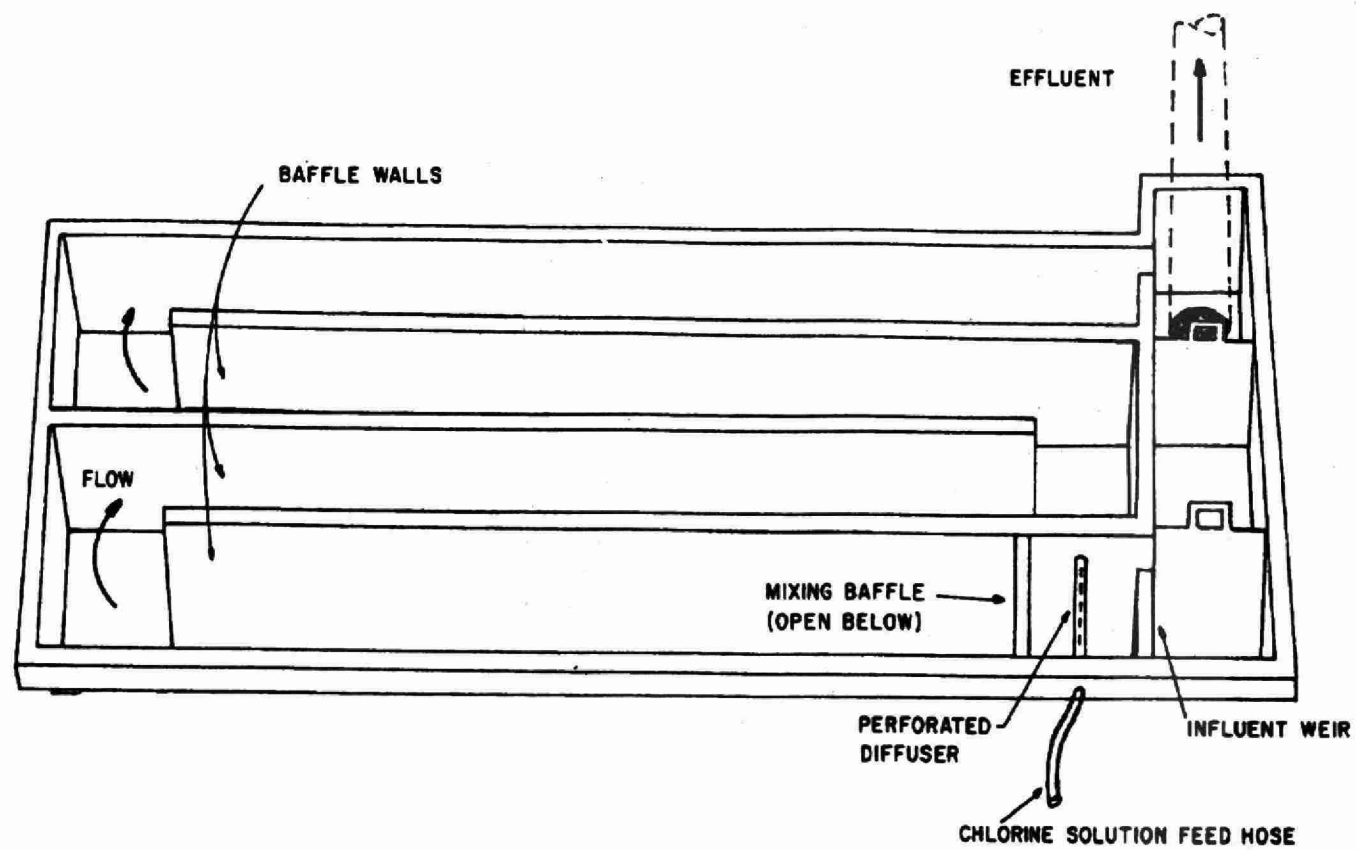
Therefore the chlorine dosage would be 12 mg/l based on the feed rate and the flow in the example.

OTHER USES OF CHLORINE

While disinfection is the most important use, there are numerous other uses of chlorination at a sewage treatment plant. However, difficulty arises since most plants, unless they are very large, are not equipped to apply chlorine at the many different locations as may be required. One should be aware of the possible uses since most are effective in correcting problem situations.

Figure 8-1

CHLORINE CONTACT BASIN



Odour Control

Odours in sewage treatment plants that are due to an anaerobic condition will usually respond to chlorination. In most cases the problem is to find the best point of application for the chlorine. In the case of primary clarifiers where the sewage has become anaerobic during the sedimentation period, the chlorine should be added to the incoming sewage. When the odour develops in the sewers due to a low velocity, the chlorine should be added far enough up the sewer so that it has adequate time to control the aerobic condition before the sewage leaves the sewer.

Industrial wastes with high oxygen demand such as come from packing houses, canneries, milk plants, etc., will turn anaerobic very rapidly and if this type of waste is found to be causing odours it should be chlorinated before it enters the sewer.

In controlling odours it is not necessary to chlorinate to a residual. It has been found that a dosage of 40-60 percent of the chlorine demand will give satisfactory control.

Aid to Sedimentation

Chlorination of raw sewage will improve the rate of settling in primary clarifiers. This is especially true when the sewage is anaerobic as it destroys the gas forming organisms and prevents the sludge from rising.

BOD Removal

Chlorine reduces the BOD of sewage in two ways. Some of the decomposable matter is oxidized by the chlorine resulting in a permanent BOD removal. Other compounds combine with the chlorine to form chloro compounds some of which are toxic to bacteria and others are no longer broken down by bacteria. The BOD reduction will vary from 15-3 percent depending on the condition of the sewage. Generally speaking the lowest reduction is obtained in fresh sewage and the highest in anaerobic sewage. A BOD reduction of 2 ppm for 1 ppm of chlorine is obtained up to the point where a chlorine residual is obtained. Beyond this point the rate of oxidation drops off.

Grease Removal

Chlorination can be used ahead of a clarifier as an aid in grease removal. The chlorine will break the grease emulsions allowing the grease to collect in larger particles that are easier to remove by skimming.

Activated Sludge Process Control

There are a number of ways that chlorine can be used to advantage in operating an activated sludge plant. In some cases sludge bulking can be controlled by chlorinating the return sludge. This will require about 5 ppm of chlorine and should be continued until a satisfactory sludge index is obtained. Sometimes at the start of this treatment the effluent becomes quite turbid but this condition should clear within a day.

When waste sludge that is being returned to the primary clarifier tends to float, chlorination of this sludge will give better settling.

When an activated sludge plant is overloaded there are several points in the plant where chlorine can be added to reduce the load. It can be used ahead of the primary clarifier to reduce BOD and increase the amount of solids settled, or it can be added to the aeration channels to aid in oxidation. When added to the final clarifier, it can be used to control biological activity and prevent flotation of the sludge. The best point to add the chlorine can only be determined by experience and varies from plant to plant.

When a plant has become anaerobic from breakdown or over loading, chlorination is the quickest way to return it to an aerobic condition. In this case chloride of lime is more effective than chlorine gas, as the pH is always low when a plant is anaerobic, and the lime raises the pH while the chlorine corrects the anaerobic condition. Care should be taken that the pH is not raised to the point where calcium carbonate is precipitated as it tends to form scale on the diffusers and plug them.

Supernatant liquor from digesters may cause a high oxygen demand on the activated sludge process that can be relieved by chlorination. Due to the high chlorine demand of this liquor, dosages as high as 80 ppm or more may be necessary to give adequate control.

Some success has also been attained in cleaning air diffusers by feeding chlorine gas into the diffuser headers.

Sludge Thickening

In some plants, sludges, both activated or primary, are thickened before they are pumped to the digester or dewatered. Chlorine can be used here to control bacterial action and better settling and concentration is obtained. To do this it is necessary to maintain a residual of 1 ppm of chlorine in the supernatant liquor above the sludge.

Breakdown of Concrete and Mortar

The hydrogen sulphide that develops in anaerobic sewage can cause other problems besides odour. This gas is quite soluble in water and will dissolve in moisture that has condensed on the walls and roof of a sewer. It is then oxidized by the air in the sewer to sulphuric acid and will dissolve the cement from the concrete and mortar and allow them to crumble. Chlorine, of course, is the answer to this problem, as it will oxidize the hydrogen sulphide before it condenses on the surface of the concrete and will also control the organisms that produce the gas.

TESTING FOR CHLORINE RESIDUAL

There are two methods used in testing for chlorine residual:

1. D.P.D. Test (Dimethyl Phenyene Diamine)
2. Amperometric Titration Test

The detailed test procedures are described in Topic 13.

D.P.D. Test

Research studies in chlorine chemistry have resulted in the development of a very simple procedure for the determination of residual chlorine compounds in water. Free or combined chlorine residual can be analyzed by this method. Differentiation and accurate determinations of these various forms of chlorine residual simplify the control of modern chlorination processes.

Amperometric Titration Test

The most accurate method of measuring free and combined chlorine residuals is by the oxidation-reduction titration procedure. This method requires the use of an electronic device called the Amperometric Titrator.

**SEWAGE TREATMENT
PROCESS CONTROL****SAMPLING AND RECORD
KEEPING****OBJECTIVES:**

The trainee will be able to:

1. Recall the purpose of sampling.
2. Define and recall the purpose of:
 - a) Grab sample
 - b) Composite sample
3. Recall the types of sampling devices.
4. Describe the two methods of collecting composite samples.
5. Recall the safety measures required to be taken when sampling.
6. Recall the location and type of samples to be taken in a plant.
7. Explain the importance of record keeping.
8. List and recall the purpose of six laboratory tests carried out to allow process control.

SAMPLING AND RECORD KEEPING

SAMPLING

Purpose

Sewage is treated to produce an effluent which will not impair the quality of the environment. If spending money is necessary to reduce pollution, then a knowledge of plant performance is necessary to justify the cost and to assess the treatment. **The purpose of routine sampling is to obtain data concerning the physical, chemical and biological characteristics of the waste stream regardless of the size or type of plant. This information can be used for control of the treatment processes, to show that regulations or standards have been observed, for estimating the effect of plant effluent on the receiving waters and for design of plant extensions.**

TYPES OF SAMPLES

Grab Sample

A **grab sample** can be defined as a single sample of wastewater taken without considering the time or the rate of flow. It is not very useful for calculating a waste loading since a single aliquot is not usually representative of average conditions. **Grab samples are only of value in determining the composition of either maximum or minimum flows.**

Composite Sample

A **composite sample** is defined as one which is built up, or composites from a series of grab samples taken at intervals during a fixed sampling period. It represents the average characteristics of the waste flow over the survey period and may be used to calculate waste loadings using the flow volume over the same period.

Composite samples are of the two types:

1. Those in which the grab samples are kept separate and analyzed separately to enable variations to be determined.
2. Those in which the grab samples are combined to form a bulk sample, all or part of which is subjected to analysis.

In the first type, a constant volume is taken at each interval regardless of the flow rate at that time. However, if a waste loading is to be calculated and it is known that the flow rate is not constant, the flow rate must be measured when each sample is taken.

In the second type of composite, where the aliquots are combined, a constant volume is taken at each interval only when the flow rate is constant. Where the flow rate varies, the amount of the aliquot taken at each interval must change to proportion to the flow rate **at the time when the sample is with-drawn from the waste stream**. For example, if at one sampling time the measured flow rate is 150,000 gpd and an aliquot of 500 ml is taken, at the next sampling only 250 ml should be taken if the measured flow rate is 75,000 gpd.

A constant time interval is usually chosen between aliquots of a composite sample, since most variations in waste characteristics occur on a time cycle. The time allowed between aliquots is determined by the variability of waste characteristics. If the characteristics vary rapidly, the aliquots must be taken frequently, say every half hour, while if the waste is of fairly uniform character, the intervals may be longer, say every hour. The most accurate average will, of course, be given by a continuously drawn sample, but unless automatic equipment is used, this will not be practical. Therefore, longer intervals such as 10, 15, or 30 minutes are often used. However, aliquots should never be taken less than once per hour. A similar principle applies when characteristics vary with volume.

To give an accurate picture of the overall quality of raw sewage entering, of plant effluent leaving, and of the processes going on within the plant, a series of three 8-hour composite samples over a 24-hour period is the ideal, and is strongly recommended. Daylight hour 8-hour composites are the next best choice, if sampling cannot be done regularly at night. In this case the occasional night composite should be attempted, even if this requires shortening a day shift to accommodate the extra hours worked.

TYPES OF SAMPLING DEVICES

There are two types of sampling devices, **automatic** and **manual**. Examples of each with their advantages and limitations are as follows:

1. Automatic

a) Vacuum Sampler

This apparatus consists of an evacuated sample container, an electrically (or mechanically) operated closing device and a length of tubing. The open end of the tube is placed in the waste stream and the timing mechanism is set to operate at the required intervals. When the closing device is opened, wastewater is drawn into the container. Advantages of this apparatus include simplicity, reasonable cost and ability to function for long periods on a small storage battery. Its chief limitation is that it can only be used on a minimum lift.

b) Pump Sampler

This apparatus consists of a sample container, a pump, and interconnecting tubing. Many types of pumps may be used, among the most useful being chemical feed pumps, due to their ability to meter accurately small volumes of liquid. A timing mechanism may be incorporated. Both vacuum and pump samplers may be equipped to sample in proportion to the flow rate. In addition to the two types described above, there are many others based on similar principles and on various types of wheels, discs and rotating scoops.

2. **Manual**

Equipment used in manual sampling is simple and consists of bottles, lines, poles (able to be joined together), bucket or bottle holders, and weights.

COLLECTION OF SAMPLES

In keeping with the prime objective of a sampling program (to obtain accurately representative samples), certain precautions must be taken to avoid errors. Whatever type of container is used, it must of course, be "clean"; rinse with sample to be taken, or clean water.

NOTE: When samples are taken through the plant, a good technique is to start with final effluent, primary effluent, raw sewage, activated sludge, and sludge return, raw sludge in digester samples. This sequence will prevent cross-contamination of samples. Where smaller samples are to be taken from a larger sample, care should be taken that the sample is representative (shake or stir sample well to ensure a thoroughly mixed smaller sample).

SAFETY SAMPLING

No sample is worth obtaining at the risk of life and limb. Safety precautions should be observed at all times, including the following:

1. Never sample alone at night where lighting is poor.
2. Never enter a tank or other vessel or a sewer unless it cannot be avoided, and then **only when it is known that the atmosphere is free from noxious gases and there is no possibility of any material entering while sampling is in progress.** Never do it alone and always use a lifeline.

3. Always remember that most organic liquids are highly inflammable and form explosive mixtures with air. **Smoke only in safe places and when sampling is completed.**
4. All chemical substances must be considered harmful (until proven otherwise) if ingested into the stomach or lungs, or by contact with the skin and eyes. It is vital to know what materials may be encountered during a survey and to use all necessary protective devices.

WHERE TO SAMPLE AND TYPE OF SAMPLE REQUIRED

REMEMBER: THE ANALYSIS IS ONLY AS GOOD AS THE SAMPLE TAKEN!

Taking good, representative samples of the wastewater entering and leaving the treatment plant is extremely important. The type of sample, where it is taken and how it is taken require conscientious care and attention since they will greatly influence the reliability of the data obtained.

The following points must be considered when taking a sample as well as where the sample is taken:

1. **Raw Sewage, Primary Effluent, Plant Effluent**
Composite samples should be taken wherever possible when sampling raw sewage, primary effluent, and/or plant effluent. A continuous 24-hour sampling period is desirable, and the sample taken should be proportional to the flow. An automatic sampler should be used. Because of the variability in raw sewage, it is important that frequent aliquots be obtained of the raw sewage and primary effluent. The same frequency is not as important when sampling plant effluent.

2. **Raw Sludge**

The composition of raw sludge can vary widely between pumping cycles, even within a single pumping cycle. To get a representative picture of the sludge, use a sample composed of at least three equal-sized grab samples. Take one grab sample at the beginning of one pumping cycle, another grab sample near the middle of a second pumping cycle, and a third grab sample near the end of a third pumping cycle.

3. **Anaerobic Digested Sludge - Primary Digestion**

The primary anaerobic digester is usually heated and the contents well mixed and nearly homogeneous. A grab sample should be enough to determine the quality of the sludge, and the sample can be taken at some convenient location, **if it is representative.**

4. **Anaerobic Digested Sludge - Secondary Digestion**

A sample from the secondary digester can be taken when the sludge is removed from tank for disposal or haulage. If possible, a composite sample should be taken, made up of one grab sample at the beginning of the day's pumping, another in the middle, and the third sample taken near the end of the pumping.

5. **Digester Supernatant**

A sample is taken whenever the supernatant is withdrawn. A composite sample of at least three equal-sized aliquots should be taken: at the beginning, the middle and near the end of the recycle.

6. **Aeration Tank (Mixed Liquor)**

The aeration tank sample is taken at the effluent end of the aeration system. By necessity, it is a grab sample, taken at about the same time each day to ensure similar hydraulic conditions, (preferably mid-way through peak load conditions). If there is more than one aeration tank, a sample should be taken from each tank. For **return sludge**, a grab sample is enough to estimate the sludge solids concentration for wasting purposes.

7. **Aerobic Digester**

The contents are usually well mixed - a grab sample should do it.

LABORATORY TESTS

General

The processes within a plant, particularly biological processes, require constant and careful attention if they are to perform efficiently, and in some cases, if they are to perform at all. All the processes used in a sewage treatment plant (sedimentation, conversion of dissolved matter to particulate matter to gases and inert products) occur in nature. The difference is time; the plant does in hours what occurs in nature in the course of many days. Because these functions are made to perform more rapidly, some method of controlling processes to obtain maximum efficiency from the plant is necessary. There are many tests which can be done even in the larger plants, because a few simple tests are enough to control the process. Those normally done in the plant depend on the equipment available and the experience of the operating personnel. Regardless of the sophistication of equipment and personnel available, only those tests necessary and relevant to controlling and assessing the processes should be carried out.

Among the lab tests carried out are the following: Settleable Solids; Mixed Liquor Suspended Solids; Sludge Volume Index; Dry Solids; Total Solids; Volatile Solids; Dissolved Oxygen Requirements; Volatile acids; Chlorine Residuals.

Settleable Solids (See Topic 11)

Settleable Solids are measured on mixed liquor samples. In this simple test, fresh mixed liquor taken at the end of the aeration tank is allowed to settle for 30 minutes in a 1-litre graduated cylinder. During the first five or ten minutes of the settling period the activated sludge should be watched for settling characteristics. A slow settling sludge will produce a clear effluent but may not allow enough time for separation in the clarifier. This can result in floc being carried over the weirs. Very fast settling sludge, on the other hand, tends to leave small particles in suspension, producing a cloudy effluent.

Mixed Liquor Suspended Solids

Mixed Liquor Suspended Solids determinations are used to control the quantity of activated sludge available to stabilize the organic matter in the incoming sewage. Analysis for suspended solids is normally done by filtering a convenient sample size (say 100 ml) on a dried, weighed filter paper (glass fibre filters are easy to use and pick up very little moisture from the air), drying the filter at 103°C and weighing it. Weighing of the filter need be to three decimal places, at most. Because it is a grab sample, results are recorded only to the nearest 100 mg/l. In controlling plant processes suspended solids are sufficient because it can be assumed that the volatile portion will remain a constant proportion of the total suspended solids. However, **volatile suspended solids** should be used for comparison between plants **especially where one plant has phosphorus removal facilities**. Volatile solids are determined on the sample previously dried for suspended solids. (Ignition of the filtered samples at 550°C will not cause any loss in weight of the glass fibre).

At smaller plants a **centrifuge** is used to estimate mixed liquor suspended solids concentrations. The centrifuge reading (usually of a 15 ml sample) of the volume occupied by the solids is compared to a **calibration curve**. The calibration curve is prepared by plotting centrifuge readings against suspended solids determined by weighing. Since this method assumes a constant density of the compacted sludge which is rarely achieved, even a recently prepared calibration curve may be in error by 30 percent.

Sludge Volume Index

Sludge Volume Index (SVI) is defined as the volume in millilitres occupied by one gram of sludge, in one litre sample, after settling for thirty minutes. It is, therefore, calculated from the results of the 30-minute settling test and mixed liquor suspended solids determination. An average SVI is about 100 though it varies from plant to plant. The important thing to watch for is a change from the norm, because it signals a change in operation conditions and probably in effluent quality.

Total Solids and Volatile Solids Test

Total solids measure the combined amount of suspended and dissolved matter in a sample. The amount is determined by weighing the residue after completely evaporating the liquid portion of a measured sample. The total solids are comprised of volatile solids (mainly organic matter of animal or plant origin), and fixed solids (mainly inorganic compounds such as mineral salts, sand and silt). Volatile solids are those solids which are lost after ignition at 550°C.

Total solids are normally used as a measure of the concentration of sludges which are difficult to filter, since the dissolved solids form an insignificant fraction of the total solids present. This test is normally done on raw and digested sludges.

Dissolved Oxygen (See Topic 12)

Dissolved Oxygen determinations are performed regularly on aeration tank contents to ensure that sufficient oxygen is being supplied to permit aerobic stabilization of organic matter. In the presence of oxygen, the organics are eventually broken down into carbon dioxide, water, nitrates, sulphates and inert minerals, none of which produces an odour.

In the absence of oxygen, the end products are carbon dioxide, methane, water, organic acids, alcohols, ammonia, hydrogen sulphide and a vile smelling dirty effluent. Both the Winkler method (including the HACH kit) and DO meters can provide accurate analysis for dissolved oxygen.

Volatile Acids

Volatile Acids analysis in **anaerobic** digesters can help to control the digestion process. Acid formation is an intermediate step in anaerobic stabilization. An accumulation of an excess amount of acids can inhibit the next stage in the breakdown of organic matter, which is the formation of lower hydrocarbons (mostly methane) and carbon dioxide. Some digesters operate normally at 100 mg/l volatile acids as acetic acid, others at 1000 mg/l. Volatile acids should be monitored regularly for **change** in acid level as an indication of impending change(s) in the process. Most digesters are well buffered against change in pH by the **alkalinity**, which is available largely in the form of ammonium bicarbonate to neutralize the acids formed, maintaining a constant pH in the range where methane-forming bacteria can thrive. It should be noted that all digester failures are not always due to, or signalled by, a rise in volatile acids content; heavy metal toxicity will produce digester failure with no change in volatile acids or pH.

Chlorine Residuals (See Topic 13)

Chlorine residuals are carried out on grab samples of plant effluent to ensure that adequate chlorine is being added to provide disinfection. While the treatment processes ahead of this stage remove a large portion of the organic matter, pathogenic (disease producing) bacteria and viruses will remain. In order to produce an effluent which is safe to re-use, disinfection using chlorine (or sodium hypochlorite) is employed. The method most commonly used to determine residual chlorine is a simple colour comparison method using orthotolidine. The development of the colour depends on time and temperature as well as the concentration of chlorine in solution.

Ministry Laboratory Tests

Other tests done by the Ministry laboratories and by larger plant laboratories are used to evaluate the performance of the plant and to estimate the effect of effluent discharge to the receiving stream. The most common analyses on plant influent and plant effluent are suspended solids, biochemical oxygen demand (BOD), total Kjeldahl nitrogen and total phosphorus.

Tests should be done for residual **total phosphorus** in the plant effluent where cost of phosphorus removal chemicals is high.

RECORDS

Obtaining analytical data is not an end in itself. The results of analyses, together with flow data, sludge volumes, gas production, etc., must be recorded in an understandable (and easy to use) form before the data can be used. Because a plant is not operated by reacting to the sewage coming in at this particular moment, but on the **expected** qualities and concentrations based on average values over the past few weeks or months, it is necessary to maintain comprehensive up-to-date records. In particular, the aeration mixed liquor concentration cannot be varied from day to day to maintain a constant F/M because BOD tests require five days of incubation. From the records, however, it is possible to establish a range of mixed liquor concentrations in which the plant will produce an acceptable effluent; the aeration tanks will then be operated in the middle of this range to allow for variations in wasting and in influent strength.

Systems for recording data can be simple or complex depending on the purpose of the record, the complexity of the operation and the judgement of the operator. In any case, the system adopted should be realistic and applicable to the particular facility. The most effective way to handle data, especially where a large number of plants are concerned, is to record on pre-printed forms. Samples of record sheets used by the Ministry of the Environment are shown in Figures 9-1, 9-2, 9-3. The first, **Plant Performance**, is common to all plants, describing influent and effluent concentrations and quantities, grit removal, phosphorus removal and chlorination. The second, **Aeration Performance**, deals with aeration tanks and aerobic digester or holding tanks where they apply. The third, **Sludge Digestion and Disposal**, records the parameters used in describing anaerobic digestion and ultimate disposal of the sludge. The three sheets are for a complete record for conventional activated sludge plants: the first two are for high rate, contact stabilization and extended aeration plants; and the first and third, for primary treatment plants with anaerobic digestion.

However up-to-date and comprehensive these records may be, they are of little value, particularly in planning plant expansion, if the figures do not accurately represent what is happening at the plant. Most of the data recorded is not entirely independent, so they can be checked against each other. All flow metering should be checked regularly and if a tank is emptied for repairs, the indicated total flow required to fill the tank should be checked against a calculated volume of the tank. Sludge volumes can usually be checked by drawdown of a sump. To determine if the sampling is representative, **mass balances** can be done on various units within a plant. In any unit in the plant, the total weight of solids going into a tank must equal the total weight out (See Figure 9-4).

In a conventional activated sludge plant and in primary plants, all solids removal by the plant are ultimately removed from the waste stream by the primary clarifier; these include solids in the raw sewage, waste activated sludge, digester supernatant, etc. The remainder of the solids appear in the primary effluent.

PLANT 19 .. to 19 ..

PLANT FLOWS

MAXIMUM RATE - mgd
 MINIMUM RATE - mgd
 TOTAL DAILY FLOW - mil gal

MIN. FREQ	MON	TUE	WED	THU	FRI	SAT	SUN	TOTAL	AVG.
d									
d									
d									

BYPASS - in million gallons (estimate where meter readings are not available)

PLANT
 PRIMARY CLARIFIERS
 AERATION SECTION
 CHLORINATION

d									
d									
d									
d									

PLANT INFLUENT

GRIT REMOVED - cu. ft.
 BOD - mg/l
 SUSPENDED SOLIDS - mg/l
 TOTAL PHOSPHORUS - mg/l
 TEMPERATURE - °C

when removed									
1/w									
1/w									
2/w									
d									

PLANT EFFLUENT (including bypass)

BOD - mg/l
 SUSPENDED SOLIDS - mg/l
 TOTAL PHOSPHORUS - mg/l

1/w									
1/w									
2/w									

PHOSPHORUS REMOVAL CHEMICALS USED (record chemicals and quantity used)

d									
d									

CHLORINATION

Cl₂ to - lb
 Cl₂ to effluent - lb
 EFFLUENT Cl₂ RESIDUAL - mg/l

d									
d									
d									

NOTE: Plants without equipment to perform the analyses should submit samples at least twice a month to the nearest MINISTRY OF THE ENVIRONMENT laboratory. The analyses requested should be checked off on the day the samples were taken.

REMARKS

Figure 9-2

WATER POLLUTION CONTROL PLANT

B - AERATION PERFORMANCE

PLANT 19... to 19...

MIN FREQ	MON	TUE	WED	THU	FRI	SAT	SUN	TOTAL	AVG
-------------	-----	-----	-----	-----	-----	-----	-----	-------	-----

AERATION INFLUENT (PRIMARY EFFLUENT)

TOTAL DAILY FLOW - mil gal
BOD - mg/l
SUSPENDED SOLIDS mg/l
TOTAL PHOSPHORUS mg/l

d									
l/w									
l/w									
l/w									

AERATION SECTION

NUMBER OF TANKS USED
30 min SETTLED SOLIDS ml/l
MLSS mg/l
MLVSS %
MOHLMAN SVI
AIR SUPPLIED - mil cu. ft.
AER² EFFLUENT TEMP. °C
F/M lb BOD/day/lb MLSS
DISS. OXYGEN mg/l (max/min)

d									
d									
l/w									
d									
d									
d									
l/w									
d	/	/	/	/	/	/	/		

RETURN and WASTE ACTIVATED SLUDGE

RETURN SL VOLUME mil gal
% of FLOW TO AERATION
SUSPENDED SOLIDS mg/l
VOLATILE SOLIDS % of SS
WASTE to mil gal

d									
d									
l/w									
l/w									
d									

SECONDARY EFFLUENT (if different from plant effluent)

BOD mg/l
SUSPENDED SOLIDS mg/l
TOTAL PHOSPHORUS mg/l

l/w									
l/w									
l/w									

AEROBIC DIGESTER or SLUDGE THICKENING TANK

30 min SETTLED SOLIDS ml/l
SUSPENDED SOLIDS mg/l
VOLATILE SOLIDS % of SS
VOLUME REMOVED gal
SITE HAULED TO *

l/w									
When Removed									

NOTE: * "SITE HAULED TO" - Use "L" for land application, "S" for sanitary landfill, "T" for transfer site (eg. storage lagoon), and "O" for others (specify). Designate each site by number (eg. L1, L2, S1, S2 etc) and keep a record of the locations.

REMARKS:

PLANT 19 .. to 19 ..

MIN FREQ	MON	TUE	WED	THU	FRI	SAT	SUN	TOTAL	AVG
-------------	-----	-----	-----	-----	-----	-----	-----	-------	-----

RAW SLUDGE

GALLONS TO DIGESTER

GALLONS TO

TOTAL SOLIDS %

VOLATILE SOLIDS % of TS

.....

.....

d									
d									
l/w									
l/w									

PRIMARY DIGESTER

TOTAL SOLIDS %

VOLATILE SOLIDS % of T.S.

ALKALINITY mg/l CaCO₃

VOLATILE ACIDS mg/l HOAc

TEMPERATURE deg C

.....

l/w									
l/w									
l/w									
l/w									
d									

DIGESTED SLUDGE

GALLONS TO

GALLONS TO

TOTAL SOLIDS %

VOLATILE SOLIDS % of T.S.

.....

.....

WHEN REMOVED									

SUPERNATANT

GALLONS TO

SUSPENDED SOLIDS mg/l

.....

WHEN REMOVED									

DIGESTER GAS

PRODUCED 1000 cu. ft.

WASTED 1000 cu. ft.

d									
d									

SLUDGE HAULAGE

LIQUID FROM cu.yd

- TOTAL SOLIDS %

- SITE HAULED TO *

DEWATERED FROM cu.yd.

- TOTAL SOLIDS %

- SITE HAULED TO *

.....

.....

.....

WHEN HAULED									

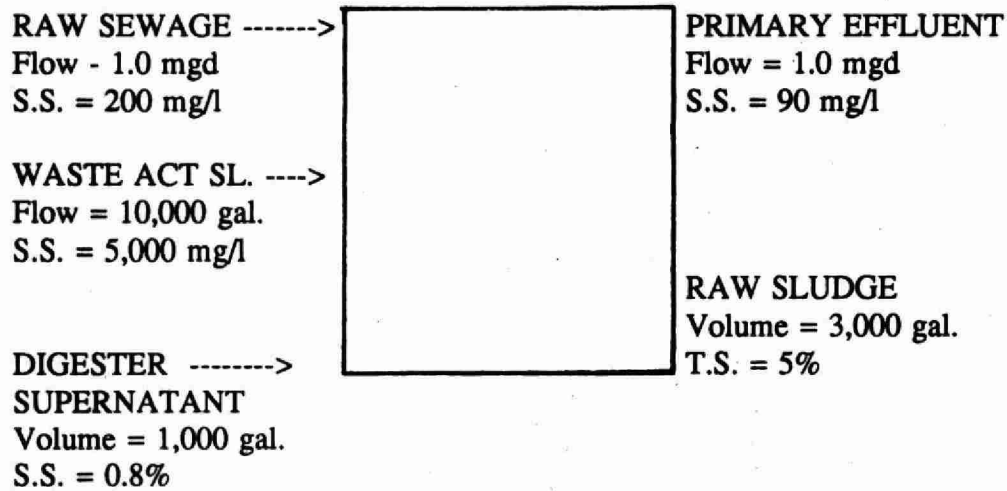
NOTE: * "SITE HAULED TO": Use "L" for Land Application
 "S" for Sanitary Landfill Site
 "T" for Transfer Site (eg. storage lagoon)
 "O" for Others (specify)

Designate each site by number (eg. L1, L2, S1, S2, etc.) and keep a record of the locations of these sites.

REMARKS

Figure 9-4

SOLIDS BALANCE



$$\begin{aligned}
 \text{SOLIDS IN} &= 1.0 \times 10 \times 200 \text{ (raw sludge)} \\
 &+ 0.01 \times 10 \times 5000 \text{ (waste sl.)} \\
 &+ 1000 \times 10 \times \frac{0.8}{100} \text{ (supernatant)} \\
 &= 2580 \text{ lb}
 \end{aligned}$$

$$\begin{aligned}
 \text{SOLIDS OUT} &= 1.0 \times 10 \times 90 \text{ (pr. eff)} \\
 &+ 3000 \times 10 \times \frac{5}{100} \text{ (raw sl.)} \\
 &= 2400 \text{ lb}
 \end{aligned}$$

SOLIDS IN should equal **SOLIDS OUT**. The above example agrees with 180 in 2500 (about 7%) and can be considered reasonable agreement. Assuming the metering is accurate, the major source of error is probably raw sludge sampling. It is not necessary to consider changes in volume due to waste activated sludge, digester supernatant or raw sludge pumping.

In activated sludge plants without primary clarifiers such as extended aeration plants, it is necessary to modify the relation somewhat. In this case, assuming 1 pound of BOD produces 0.7 pound of MLSS, the mass balance in the aeration tank becomes:

$$\text{lb Solids In} = \text{lb BOD} \times 0.7$$

$$\begin{aligned} \text{lb Solids Out} = & \text{accumulation (or decrease) in MLSS (lb)} \\ & + \text{lb waste activated sludge} \\ & + \text{lb SS in effluent} \end{aligned}$$

The solids in the bottom of the clarifier can be ignored. However, in contact stabilization plants it is necessary to consider the solids in the reaeration tank.

Mass balances can be done on anaerobic digesters though a fairly long period of time should be used to establish average values. Again, Solids In (in the form of raw sludge) equals Solids Out (as digested sludge and supernatant) and the solids lost to digestion.

Sampling points and/or methods should be altered, if necessary, to produce results which are consistent within the plant, that is, **for any unit within the plant, solids in plus accumulation must equal solids out plus destruction.**

CONCLUSIONS

Because plants are operated on the basis of what happened in the past, up-to-date records are necessary to operate a plant efficiently, following the trends in the changing sewage characteristics. In order to have reliable records, representative samples must be taken. Analysis of the samples will produce results by which the processes can be operated in the best range for that plant.

SUBJECT:

TOPIC: 10

SEWAGE TREATMENT

SAFETY OPERATION

OBJECTIVES:

The trainee will be able to:

1. Name three (personal) hazards common to treatment plants.
2. Recall the safety rules to follow when working in or around:
 - a) Wet Wells
 - b) Chlorine Rooms
 - c) The Laboratory
 - d) Settling Tanks
 - e) Digesters
3. List at least eleven precautions to take for electrical maintenance.
4. Recall eight rules to follow to prevent body infection.
5. Recall ten general safety practices to be followed when working in the plant.

SAFETY PRACTICES IN TREATMENT PLANTS

INTRODUCTION

The dangers associated with plant operations emphasize the need for safety practices. Physical injuries and body infections are a continuous threat and occur with regularity. Explosions and asphyxiations from gases or oxygen deficiency occur. Although infrequent at any particular location, country-wide such accidents are a daily happening. These occupational hazards may be largely avoided by the execution of safe practices and the use of safety equipment. The dangers are many and carelessness all too frequently prevails until an accident results. Then it is too late.

It is the responsibility of supervisors to acquaint themselves with the hazards associated with plant maintenance and operation and to take steps to avoid them. Accident prevention is the result of thoughtfulness and the application of a few basic principles and knowledge of the hazards involved. It has been said that the "A,B,C" of accident prevention is "Always Be Careful". One must learn how to be careful and what to avoid. With this knowledge one can then always think and practice safety.

HAZARDS

The overall dangers of accidents are much the same whether in manholes, pumping stations or treatment plants. These result from:

1. Body infections
2. Physical, injuries
3. Dangerous noxious gases or vapours, oxygen deficiencies and hazardous chemicals.

BODY INFECTION

Workers in treatment plants are exposed to the hazards of water-borne diseases, including Typhoid Fever, Amoebic Dysentery, Infectious Jaundice and other intestinal infections. Tetanus and skin infections must also be guarded against.

A majority of infections reach the body by way of the mouth, nose, eyes and ears. Therefore, washing your hands is a must before eating or smoking. Wear protection gloves where possible. Soap preparations requiring no water rinse are available for field use. The common drinking cup should be banned, each man should have and use his own.

Typhoid and Tetanus inoculations are recommended. These may be obtained free of charge from local Health Officers.

This hazard to plant personnel although very real and ever present can be largely reduced by the operator himself by following a few basic rules of personal hygiene. A few of these self applied rules are as follows:

1. Never eat your lunch or put anything into your mouth without first washing your hands.
2. Refrain from smoking while working in open tanks, on pumps, or cleaning out grit channels, etc. Remember you inhale or ingest the filth that collects on the cigarette from dirty hands. Save your smoking time for lunch hours or at home.
3. A good policy is "never put your hands above your collar when working on plant equipment".
4. Rubber or rubberized cotton gloves, rubber boots and coveralls are designed for body protection against dampness and contact with dirt, wear them at all times when working in tanks, etc.
5. Rubberized or rain suits can be worn in very wet or dirty places and can be washed off with a hose and brush, the same as rubber boots.
6. Always wear your rubber boots when working in tanks, washing down etc., don't wear your street shoes.
7. Don't wear your rubber boots or coveralls in your car or at home.
8. Wear rubber or plastic coated gloves when cleaning out pumps, handling hoses, etc.

9. Don't just wash your hands before going home, wash your face too, there is as much of your face to carry germs as there is of your hands.
10. Wear a hat when working around sludge tanks, cleaning out grit and other channels, don't go home with your head resembling a mop that just wiped up the floor around a cleaned out pump.
11. Keep your finger nails cut short and clean, they are excellent carrying places for dirt and germs.

PHYSICAL INJURIES - First Aid

Except for minor injuries, wounds should be treated by a doctor and reported for possible Workman's Compensation. Service truck and plants must have first aid kits. It is recommended that all plant personnel should receive "St. John Ambulance" first aid instruction.

It is a "Compensation Board" regulation that any plant having five (5) or more people working as a group on any shift, one of them is required to hold a "St. John Ambulance Certificate" in first aid. Remember, no cut or scratch is too minor to receive attention.

HAZARDOUS MATERIALS

The dangers of hazardous material are dealt with later in this topic.

THE PLANT SAFETY PROGRAM

Before starting a safety program, the full co-operation and active support of management is needed. One person in the utility organization must be responsible for the program. In a small water works system, that person may be the superintendent, while in a larger organization, another person who can devote part or full time to the job can be appointed.

The next step in setting up the program is to provide for:

1. Keeping injury records
2. Identification and location of the hazards
3. Making equipment, plant arrangements and working methods safe
4. Getting employees interested in safety
5. Controlling work habits

Injury Records

The keeping of injury records is basic to a safety program. With complete records, the program is given direction and is sure of success. The records should be kept brief but must contain all pertinent data. The forms should cover such items as:

1. Accident report
2. Description of accident
3. Physician's statement
4. Corrective action taken
5. Accident analysis chart

Locating the Hazards

The person responsible for the safety program should be constantly on the alert for hazards which may cause an injury to an employee. One of the best methods of attacking this problem is to search the records for the conditions and situations that have produced injuries. Records like this show the need for a corrective program.

Many other sources of information on hazardous conditions are available. These include safety manuals, insurance company brochures, etc. They should be used freely and frequently.

Equipment, Plant Arrangements, Working Methods

Nothing prevents an accident as effectively as the elimination of the cause. To preach safety while permitting unsafe conditions will discourage the cooperation required from employees. Only when safety is integrated with the job are workers convinced that the person responsible for safety wants to prevent accidents.

Some Protective Safety Equipment

The need for protective safety equipment in an accident prevention program has proven its value many times; the program cannot be successful if any phase of accident prevention is overlooked.

Use safety equipment as it was meant to be used. This should be compulsory during the performance of hazardous jobs. **Protect eyes and face** when there is any possibility of injuries from hand tools, power tools, welding equipment, etc. **Protect feet** with safety shoes to safeguard against injuries while breaking pavements, tamping trenches, handling materials, etc.

Protect head (with hard hats) to prevent serious injuries in construction, excavation or electrical work.

Protect hands (with gloves) to prevent injuries from occurring when handling materials, sharp objects, chemicals or electrical equipment.

Use air packs when hazards such as chlorine, painting or dusty areas exist.

Prevent accidents due to falls by using safety belts, scaffolds, etc.

GENERAL PLANT SAFETY

When working at the plant, observe the following common sense rules:

Keep walkways clear of loose objects such as pails, shovels, loose rope, etc.

Wipe up grease and oil **immediately**; salt or sand icy walks.

Pick up all tools, clean them and return them to their storage areas.

When it is necessary to use tools in an empty tank or manhole, etc., lower them in a pail on a rope and remove them in the same way. Brooms and shovels can also be transported by rope. **Do not attempt to climb up and down ladders with your hands full of tools.**

Do not overload yourself when using stairways. Keep your load small enough to be able to see over it. Always keep one hand free to use the hand-rail.

Do not try to climb up or down a ladder or over a railing when handling a hose under pressure.

Always wear hip wader rubber boots with good treaded soles when washing down the floor of any tank. **Do not** wear rubber boots with worn soles and heels.

Always wear the rubber clothing provided when working in a narrow or confined passage where grit or sludge accumulates.

Always wear rubber or plastic coated, waterproof gloves when cleaning pumps, handling hoses, removing grit or sludge, etc.

When it is necessary to use an extension ladder to enter any empty tank, use the collector arms in the clarifiers to back-stop the ladder legs. In an aeration tank, lash the ladder. Enter the tank from a walkway (not from a narrow dividing wall) and **always lash the ladder to a hand-rail.**

Always wear hard hats when working below ground level (in tanks, manholes, etc.) or under scaffolding.

Do not hang clothes on electrical disconnect handles, light switches or control panel knobs.

Replace all manhole covers and trap doors to wells. Close after using. If it is necessary to leave them open, **protect them with guard-rails.**

Use the proper tool when removing or replacing manhole covers. **Do not** attempt to move or close a manhole cover with your hands.

When working in manholes located in a street or road, post signs with blinking amber lights and red flags at each approach to the area.

Do not pull up grit-filled pails by rope when removing from tanks or wet wells. Use an "A" frame and pulley or some other type of support with a pulley. Be sure the support and pulley are fastened firmly to prevent them from toppling over during use.

Always wear a safety belt with a short rope and a safety snap when leaning out through the railings over any tank (or cleaning out spray nozzles, etc.)

Be very careful during repair work on fuel systems of gasoline engines. **Close the shut-off valve** from the tank and **be sure there is adequate ventilation** while draining the fuel system.

Check the ventilation of any enclosed or underground areas when gasoline operated pumps are to be used.

Do not refill a gas engine when in operation or while still hot. **Remove** spark plug from engine before cleaning out pump unit.

Building Maintenance

Periodic inspections are necessary to eliminate hazards (fire safeguards, etc.). Suggested repairs for safety should receive immediate attention. Floors, hallways, and stairways should always be well lighted, clean, orderly and free from oil, dirt and debris. Immediate repairs of hazardous electrical outlets and fixtures should be routine. Adequate sanitary facilities for employees must be provided. Hand-rails on steps and stairways should always be provided and used. **Good house-keeping must be maintained.**

Hand Tools

Hand tools are the cause of many accidents and injuries when improperly used and in unsafe condition. Therefore, use the right tool for the right job in the right way. Use protective safety equipment where there is a job hazard. Keep the work area clear of hazards, with plenty of working space for solid footing. Tools should be in good condition and used for the purpose for which they were intended.

Portable and Power Tools

All equipment should be grounded. Check wiring and equipment regularly for defects. Be very careful when using equipment in wet areas. Use protective safety equipment when operating grinders, buffers, or other tools when there is danger of flying material.

Tools and Machines

Use protective equipment when operating power equipment if there is any chance of flying objects or other injuries. Inspect all tools and equipment for safe operation. Necessary repairs or replacements should be made immediately. **Repair power tools and machinery only when the equipment is turned off.**

Welding

Use the proper protective equipment at all times. Check for fire hazards before cutting or welding in areas of inflammable or explosive mixtures. **Only authorized personnel should operate welding equipment. The Ministry of Labour requires a 2-3/4 lb fire extinguisher to be fastened to the welding truck.**

Inspections of Tools and Equipment

Periodic inspections should be made of tools and equipment so that those that are broken or worn out may be replaced. **Report worn or broken equipment** and be sure they are replaced or repaired as soon as possible.

Ladders

Ladders should be inspected periodically and maintained in good order. **Use safety belts** when awkward positions are necessary for the work. **Do not use metal ladders for electrical work.**

Lifting

Always lift with the leg muscles instead of the back and be sure your footing is secure. Bend your knees and keep your back straight. Don't turn or twist your body when lifting. Get help if load is too heavy or awkward to handle. Use mechanical device for lifting wherever possible.

Sanitation

Washrooms, toilets, locker rooms, drinking fountains and showers that are clean, ventilated and adequately built are good for employee morale. Clean drinking water and paper cups should be available at each plant, especially if the employees are exposed to skin irritant materials.

Storerooms

Good housekeeping must be maintained at all times. Space should be well arranged to permit proper storage, handling and movement of materials. Inspections should be made regularly for fire hazards. Fire extinguishers should be in good order and easily accessible.

Working Area

A safe working area must be provided for efficient work. In the field, traffic should be controlled by the use of traffic cones, barricades, flags, etc., to protect the workmen as well as the public. In the material yard and storerooms, good house-keeping and properly planned storage and work areas must be provided for safe working practices. Shops, plants and offices should be planned for the most efficient production.

Trucks and Equipment

Routine inspections of trucks and equipment should be made. Any need for repairs should be reported and acted on as soon as possible. Only qualified and licensed operators should be permitted to use and operate vehicles and equipment. Never permit riders on trucks or other mobile equipment. Check electrical and any other hazards constantly when moving heavy equipment. All trucks should be equipped with first aid kits, fire extinguishers, and flares.

Barricades and Traffic Control

An adequate and safe work area must be protected. Sufficient traffic cones and barricades should always be carried by crews assigned to construction or maintenance work in streets. Paint barricades bright, visible colours and keep them in good condition. Be sure warning signs, flags, flares are adequate and in position where they can be easily seen.

EQUIPMENT SERVICING

When servicing plant and equipment, do not:

1. Grease or oil or attempt to service any machinery while it is in operation. Pumps on automatic control must be locked out and key carried by the operator during servicing.
2. Make any adjustments to operating machinery while alone. If it is necessary to run the unit to adjust it, a second man must be present and be beside the stop-and-go switch.
3. Work around electrical panels, disconnects or switches alone.
4. Enter any crawl space under flooring for any purpose until the area has been ventilated. A second man should be present.
5. Service pumps and shafts in the dry wells of pumping stations, and in plants where the pumps and shafts are less than three feet apart, without shutting off all pumps and locking them out.
6. Under any circumstances, attempt to grease or service pump shafting while standing on beams, piping, loose planks, guard rails, or by leaning out, over or through guard rails. If a ladder must be used, then a second man must be present to hold the ladder steady and to provide any other assistance.

PRECAUTIONS FOR ELECTRICAL MAINTENANCE

1. Plan safety into each job. Orderliness and good house-keeping are essential for your safety and the safety of others.
2. Each employee shall be qualified both in experience and general knowledge to perform the particular electrical work which he is assigned. Outside contractor to be called in.
3. Study the job carefully to determine all of the hazards present and to see that all necessary safeguards and safety devices are provided for safe working conditions.
4. Examine all safety devices before they are used to ensure that they are in good condition.
5. In all cases where work is being performed on or close to live conductors or equipment, at least two men shall work together. When it is necessary for one to leave, the other workman shall not continue the work until the first man returns.
6. Consider the results of each action. There is no reason for you to take chances that will endanger yourself and others.
7. Satisfy yourself you are working under safe conditions. The care exercised by others can not be relied upon.
8. Wear close fitting clothing, keep sleeves rolled down, avoid wearing unnecessary articles while working on or close to live circuits or apparatus.
9. Use only approved types of rubber or leather gloves.
10. Protect yourself by placing an insulated medium between you and ground or grounded apparatus to keep any part of your body from providing a path for electrical current when working on conductors or apparatus that may be energized.
11. Use rubber mats when working on any electrical control panel or switch and disconnect boxes.
12. Open and close switches completely with a firm positive motion. Switches in a partly open position may arc or cause a flash-over with damaging results to the switch and possible injuries to the operator.
13. Open switches fully before removing fuses. To remove a fuse from a circuit carrying a current without opening the switch is particularly hazardous. Use an approved low-voltage fuse puller to remove fuses on a circuit of less than 500 volts (where no switch is provided) whether a disconnect is, provided or not. Remove fuses by breaking contact with the hot side of the circuit first. Use the reverse procedure when replacing fuses. Insert the fuse in the cold terminal first.

14. Do not stand directly in front of panel to remove fuses or shut off disconnects.
15. Shut off the power when examining or making repairs or alterations on light and power circuits. When this is impractical Head Office must be contacted for further instructions before proceeding with the work.
16. Consider all electrical circuits to be dangerous. Treat dead circuits as though they were live. This may prevent an accident as the circuit may be closed through an error of some other person.
17. Exercise extreme care when required to locate troubles on a series lamp circuit, before repairs are made make sure the power is cut off.
18. Lock or block open the control devices, open disconnect switches or remove fuses before examining, repairing or working on power circuits. After these precautions have been taken, attach tie-up tags worded "WORKMEN ARE WORKING ON LINE". The tag shall bear the name of the workman. Tie-up tags shall remain on the opened devices until removed by the workman whose name appears on the tag. If the workman leaves without removing his tag, it may be removed only on authorization of Head Office.
19. Before working on line circuits at a point remote from the control switch, which has been tagged, it is recommended that the conductors be grounded at a point on the line between the switch and the work station.
20. Make a complete check of the circuit before applying power for the first time. This is to be done by a qualified man in charge of the repairs, all other workmen to stand off at a safe distance.

FIRE PROTECTION

Good housekeeping is the basis for fire prevention. Inspections should be made periodically and correction of fire hazards should be made as soon as possible. Consult local fire departments for recommendations.

Each operator should have first hand knowledge of fire extinguisher, its ABC rating point of contact and time of operation.

A CO₂ fire extinguisher can only be used in an open area where the chance of using up the local oxygen is minimal. Never grab the horn of the extinguisher to direct the CO₂. The gas being expelled will freeze your hand to the horn causing serious injury. There is a handle provided. Do not direct the CO₂ at anyone. To fight the fire you must approach the fire from upwind, pull the pin and aim directly on the burning area.

The approximate operating time for CO₂ fire extinguishers is as follows:

2 1/2 lb.	10 sec. +/- 2 sec.	2. BC.
5 lb.	14 sec. +/- 2 sec.	4. BC.
10 lb.	14 sec. +/- 3 sec.	6. BC.
15 lb.	25 sec. +/- 4 sec.	8. BC.
20 lb.	30 sec. +/- 4 sec.	8. BC.

NOTE: The 2. BC etc., refers to the type of fires and area the extinguisher covers. (BC) indicates electrical, gas, oil type fires, "A" type are wood, paper, etc., CO₂ will not be effective on "A" type fires. (2) indicates the extinguisher will put out a fire of not more than 2 square feet in area. Weight indicated refers to contents only.

A dry Chemical extinguisher can be used in any area. Approach from upwind and pull the pin, you do not have to stand as close to the fire as with CO₂. Dry Chemical will put a blanket of chemical over the fire, smothering it.

NOTE:

1. All extinguishers must be refilled after using no matter what amount has been used.
2. All extinguishers must be hydrostatically tested every five (5) years.

CHEMICAL HANDLING AND STORAGE

The Industrial Safety Act, Ministry of Labour, states that the employer is responsible for providing the necessary protective equipment and clothing for handling dangerous materials. It is the responsibility of the employee, both to his employer and to himself to use and maintain them.

Eyewash fountains and deluge showers must be located within fifteen (15) feet of the entrance to any chemical handling area. Plenty of water should be available for washing up after handling chemicals. Protective clothing should be washed after use.

All areas where solvents or other compounds are used and stored must be well ventilated. The working area must be designed and constructed for the safety and convenience of the worker and for his efficient production. The ventilation should be by mechanical means **with the air intake drawing air from the outside**. In rooms where lime and other dry types of chemicals are used, install dust accumulators in the air discharge pipe.

Operate exhaust fans when handling any chemical whether liquid or dry.

Wear rubber boots, apron, gloves and eye shield or goggles when handling liquids.
Wear nose and mouth filter masks and goggles when handling dry chemicals.

LABORATORY

1. A thorough knowledge of first aid for dealing with lab accidents is essential. Know the relevant sections of the antidote chart.
2. Wear protective clothing.
3. Practice good housekeeping. Keep all unnecessary equipment out of working areas. Use a separate marked container for broken glass.
4. Areas around sinks and taps should be kept clear so that chemicals spilled on one's hands or person can be washed off quickly.
5. Wipe up all spills immediately.
6. All reagent bottles must be clearly labelled so they can be identified. The date when the reagent was made up, or received, should be on the label since some chemicals, particularly nitrogen compounds, become unstable with age.
7. When diluting concentrated acids or bases, always add slowly to the water allowing time to cool. Use only heat resistant (Pyrex) glassware. When diluting sulphuric acid or when making up a solution of sodium hydroxide, cool the solution in a water bath.
8. Chromic acid cleaning solution is a mixture of sodium or potassium dichromat in concentrated Sulphuric acid. It dehydrates and oxidizes most organic matter, including clothing. **TREAT IT WITH CARE!**
9. Use water as a lubricant when making glass to hose connections. For vinyl tubing, hot water can be used to make the plastic more pliable. Gloves should be worn when making hose connections to glass tubing.
10. Suction bulbs should be used on all pipets. A valved type sold as a "PROPIPET" will save fumbling.
11. Combining chemicals found in the laboratory without knowing how they will react can produce unexpected and unpleasant results.
12. When disposing of any chemical in the sink, dilute with plenty of water.
13. Bottles of hazardous liquids should be stored near floor level in ventilated cupboards.
14. **HASTE MAKES WASTE** (and accidents). Planning can save far more time than hurrying (and produces fewer mistakes).

Characteristics of Dangerous Gases and Gas Fuels

Refer to Tables 10-1 and 10-2.

SAFETY PRACTICES IN WORK AREAS

The following paragraphs list some of the specific safety measures an operator should observe when carrying out his responsibilities in a plant.

No Smoking

1. Influent buildings
2. Detritor rooms
3. Wet and dry wells of plant pumping stations
4. Pump rooms containing raw sludge pumps
5. Tunnels having pipe galleries carrying digester or natural gas pipe
6. Digester, digester buildings
7. Sewers, manholes
8. Sludge holding tanks (covered)
9. Near sludge thickening tanks while mixing with compressed air is underway.
10. Sludge conditioning tanks in filter rooms
11. Sludge loading pipes to trucks
12. Sludge discharge pipes to drying beds

Hazardous Gases and Fuels

In handling chemicals in the sewage treatment process, the general safety requirements outlined earlier should be met. Operators should be aware of the hazards associated with chemicals used in a sludge treatment.

Sludge is treated with chemicals to improve its dewater ability. Many chemicals have been used for this treatment, such as sulphuric acid, alum, chlorinated copperas, and ferrous sulphate, but, because of its low cost, ferric chloride with or without lime has been the most commonly used.

Concentrated ferric chloride decomposes in the presence of light or moist air to yield hydrochloric acid and is therefore extremely corrosive. Consequently, all tanks, piping, and valves that handle FeCl_3 should be either rubber-lined or made of acid resistant plastic. Ferric chloride storage facilities should be well vented. Employees handling this chemical should be equipped with acid-resistant goggles and rubber gloves, rubber suits, and rubber boots. At least one emergency eye bath and safety shower within a radius of 25 feet should be available for employees in areas where FeCl_3 is stored or used. In addition, the correct type of canister gas masks or self-contained air breathing equipment should be available in all areas where HCl gas could accumulate. Other chemicals used for sludge treatment require similar safety precautions.

Influent Building

1. Area must be tested for noxious gases or vapours and the percentage of oxygen before entry. It is essential these factors be known.
2. Safety goggles must be worn around Barminator, Comminator and Mechanical Bar Screens.
3. Two men must be present when working in this area.

Grit Removal Area

1. Aerated Grit Chambers

- a) Safety goggles must be worn because of the ever present splashing.
- b) Rubber boots must be worn.
- c) If a "Clam Bucket" with an overhead crane is used, care must be taken on entry to cab from the ladder.
- d) Ground man must wear a hard hat and always be aware of the location of the Clam Bucket.

2. Detritor and Raker Arm

- a) Hands must be kept clear of the raker blades.
- b) Do not step over the raker arm.

Primary and Secondary Settling Tanks

- 1. During cleaning of launder area, two men must be present.
- 2. A safety harness and short safety line must be worn when cleaning launders.
- 3. Safety bars should be located across outfall pit of launders to prevent operator from stepping into it.
- 4. At no time should the operator climb out on the centre ring of a round clarifier or step on the flytes of a rectangular clarifier without a safety harness and life line.

Pump Rooms

- 1. "Caution Pumps on Automatic" signs must be posted.
- 2. Vent fans must be on.

Aeration Tanks

These areas can become extremely slippery from the spray, great care in walking is required.

1. Diffused Air

- a) Ear muff type noise protection must be worn when in the blower room. The noise level is usually over 90 db., which is in the hearing discomfort range.
- b) Metal catwalks must be secured and the ends not turned up.
- c) When cleaning spray defoamers a short life line and safety harness must be worn.

2. Mechanical Type

- a) Serious accidents have been caused by the wearing of loose clothing when working around motor drive shafts. Wear proper fitting clothing.
- b) Centre catwalks require safety railings on either side.
- c) Do not stand on aerator discs, as they may start up unexpectedly.

Digesters

- 1. Non-sparking shoes must be worn.
- 2. The vent fan must be turned on before entering control room.
- 3. Metal roofs require a non-slipping walkway to centre P.R.V. valve.
- 4. Do not weld in the area.

Chlorine Buildings

1. The following signs must be posted outside the room door:
 - a) Turn on Vent Fan
 - b) Danger Chlorine Storage
2. A "Fresh Air" air pack must be located within 15 feet of room door.
3. An eye wash bath must be located within 15 feet of room door.
4. Mechanical ventilation of the chlorine room shall be sufficient to produce 30 air changes an hour taking suction from within 18 inches of the floor.
5. Operator must wear safety goggles and a pair of rubberized gloves.
6. Two operators shall be present for cylinder changing.
7. Fresh strong ammonia must be used for leak detection.
8. The chlorine room must NOT be used as a plant storage area.

Wet Wells

A wet well is classified as a confined space under Section 84-88 of the Industrial Safety Act, 1975. Before entering the operator must:

1. Test for oxygen content using an oxygen meter. DO NOT ENTER unless the oxygen content in the atmosphere registers between 18% and 23%.
2. Test the noxious gases and vapours using a combustible gas analyzer.
3. Test for Hydrogen Sulphide using the colorimetric test. Tests for other gases may also be necessary.

The operator must also take the following precautions on entry:

1. If any atmospheric contamination is suspected, a fixed or portable vent fan of 700 cfm capacity must be used before and during entry. If no vent fan is available, a portable air pack must be worn.
2. Explosion and waterproof lighting must be used.
3. An operator with a man hoist must be located at all times at the entrance to the wet well to monitor the meters and observe the operator inside.
4. If a man hoist is not available two operators must be at the entrance.
5. A parachute type harness and lifeline and hard hat must be worn.
6. A step-through parting is required at the ladder entrance.

Dry Wells

1. Vent fan shall be started before entering the pumping station and left operating continuously while the operator is in the station.
2. "DANGER PUMPS ON AUTOMATIC CONTROLLER" signs should be posted at the control panel floor level, and the pump floor level.
3. "NO SMOKING" signs should be posted at the pump floor level.
4. Lock out switches at control panel when working on any pump at any floor level.

TABLE 10 - 1

CHARACTERISTICS OF DANGEROUS GASES ENCOUNTERED IN SEWERS, SEWAGE PUMPING STATIONS AND SEWAGE TREATMENT PLANTS

GAS	CHEMICAL FORMULA	COMMON PROPERTIES*	SPECIFIC GRAVITY OR VAPOUR DENSITY (AIR=1)	PHYSIOLOGICAL EFFECT*	MAX SAFE 60-MIN. EXPOSURE (% BY VOL. IN AIR)	MAX SAFE 8-HR. EXPOSURE (% BY VOL. IN AIR)	EXPLOSIVE RANGE (% BY VOL. IN AIR) LOWER UPPER LIMIT	LIKELY LOCATION OF HIGHEST CONCENTRATION	MOST COMMON SOURCES
CARBON DIOXIDE	CO ₂	COLORLESS, ODORLESS WHEN BREATHED IN LARGE QUANTITIES MAY CAUSE ACID TASTE, NONFLAMMABLE. NOT GENERALLY PRESENT IN DANGEROUS AMOUNTS UNLESS O ₂ DEFICIENCY	1.59	CANNOT BE ENDURED AT 10% MORE THAN FEW MIN, EVEN IF SUBJECT IS AT REST AND OXYGEN CONTENT NORMAL. ACTS ON RESPIRATORY NERVES.	4 TO 6	- -	- -	AT BOTTOM; WHEN HEATED MAY STRATIFY AT POINTS ABOVE BOTTOM.	PRODUCTS OF COMBUSTION, SEWER GAS, SLUDGE, ALSO ISSUES FROM CARBONACEOUS STRATA.
CARBON MONOXIDE	CO	COLORLESS, ODORLESS, TASTELESS, FLAMMABLE, POISONOUS.	0.97	COMBINES WITH HAEMOGLOBIN OF BLOOD. UNCONSCIOUSNESS IN 30 MIN AT 0.2 TO 0.25%. FATAL IN 4 HR AT 0.1%. HEADACHE IN FEW HR AT 0.02%	0.04	0.01	12.5 70.0	NEAR TOP, ESPECIALLY IF PRESENT WITH ILLUMINATING GAS.	MANUFACTURED GAS, FLUE GAS, PRODUCTS OF COMBUSTION, MOTOR EXHAUST, FIRES OF ALMOST ANY KIND.
GASOLINE	C ₇ H ₁₆ TO C ₁₂ H ₂₆	COLORLESS, ODOR NOTICEABLE AT 0.03% FLAMMABLE.	3.0 TO 4.0	ANESTHETIC EFFECTS WHEN INHALED. RAPIDLY FATAL AT 2.4%. DANGEROUS FOR SHORT EXPOSURE AT 1.1 TO 2.2%	0.4 TO 0.7	0.10	1.3 6.0	AT BOTTOM	SERVICE STATIONS, GARAGES, STORAGE TANKS, AND HOUSES.
HYDROGEN	H ₂	COLORLESS, ODORLESS, TASTELESS. FLAMMABLE.	0.07	ACTS MECHANICALLY TO DEPRIVE TISSUES OF OXYGEN. DOES NOT SUPPORT LIFE.	-	-	4.0 74.0	AT TOP	MANUFACTURES GAS, SLUDGE DIGESTION, TANK GAS, ELECTROLYSIS OF WATER, RARELY FROM ROCK STRATA.

* PERCENTAGES SHOWN REPRESENT VOLUME OF GAS IN AIR.

TABLE 10 - 1

CHARACTERISTICS OF DANGEROUS GASES (CONTINUED)

GAS	CHEMICAL FORMULA	COMMON PROPERTIES*	SPECIFIC GRAVITY OR VAPOUR DENSITY (AIR=1)	PHYSIOLOGICAL EFFECT*	MAX SAFE 60-MIN. EXPOSURE (% BY VOL. IN AIR)	MAX SAFE 8-HR. EXPOSURE (% BY VOL. IN AIR)	EXPLOSIVE RANGE (% BY VOL. IN AIR) LOWER UPPER LIMIT	LIKELY LOCATION OF HIGHEST CONCENTRATION	MOST COMMON SOURCES
HYDROGEN SULFIDE	H ₂ S	ROTTEN EGG ODOR IN SMALL CONC. EXPOSURE FOR 2 TO 5 MIN AT 0.01% IMPAIRS SENSE OF SMELL. ODOR NOT EVIDENT AT HIGH CONC. COLORLESS, FLAMMABLE.	1.19	IMPAIRS SENSE OF SMELL RAPIDLY AS CONC. INCREASES. DEATH IN FEW MIN AT 0.2% EXPOSURE TO 0.07 TO 0.1% RAPIDLY CAUSES ACUTE POISONING. PARALYZES RESPIRATORY CENTRE.	0.02	0.002	4.3 46.0	NEAR BOTTOM, BUT MAY BE ABOVE BOTTOM IF AIR IS HEATED & HIGHLY HUMID.	COAL GAS, PETROLEUM SEWER GAS, FUMES FROM BLASTING UNDER SOME CONDITIONS SLUDGE GAS.
METHANE	CH ₄	COLORLESS, ODORLESS, TASTELESS, FLAMMABLE.	0.55	ACTS MECHANICALLY TO DEPRIVE TISSUES OF OXYGEN. DOES NOT SUPPORT LIFE.	PROBABLY NO LIMIT PROVIDED OXYGEN PERCENTAGE IS SUFFICIENT FOR LIFE.		5.0 15.0	AT TOP, INCREASING TO CERTAIN DEPTH.	NATURAL GAS, SLUDGE GAS, MANUFACTURED GAS, SEWER GAS. STRATA OF SEDIMENTARY ORIGIN. IN SWAMPS OR MARSHES.
NITROGEN	N ₂	COLORLESS, TASTELESS. NONFLAMMABLE. PRINCIPAL CONSTITUENT OF AIR (ABOUT 79%)	0.97	PHYSIOLOGICALLY INERT			- -	NEAR TOP, BUT MAY BE FOUND NEAR BOTTOM.	SEWER GAS, SLUDGE GAS. ALSO ISSUES FROM SOME ROCK STRATA.
OXYGEN (IN AIR)	O ₂	COLORLESS, ODORLESS.	1.11	NORMAL AIR CONTAINS 20.9% OF O ₂ . MAN CAN TOLERATE DOWN TO 12% MIN SAFE 8-HR EXPOSURE, 14 TO 15%. BELOW 10% DANGEROUS TO LIFE. BELOW 5 TO 7% PROBABLY FATAL.			- -	VARIABLE AT DIFFERENT LEVELS.	OXYGEN DEPLETION FROM POOR VENTILATION AND ABSORPTION, OR CHEMICAL CONSUMPTION OF OXYGEN.
SLUDGE GAS	-	VARIABLE	VARIABLE	WILL NOT SUPPORT LIFE.	NO DATA, WOULD VARY WIDELY WITH COMPOSITION.		5.3 19.3	NEAR TOP OF STRUCTURE.	FROM DIGESTION OF SLUDGE.

* PERCENTAGES SHOWN REPRESENT VOLUME OF GAS IN AIR.

TABLE 10-2

CHARACTERISTICS OF GAS FUELS

GAS	CHEMICAL FORMULA	B.T.U. CALORIFIC VALVE	SPECIFIC GRAVITY OR VAPOUR DENSITY	EXPLOSIVE LIMITS IN AIR % BY VOLUME		THEORETICAL AIR REQUIRED FOR COMPLETE COMBUSTION	MINIMUM IGNITION TEMPERATURE °FAHRENHEIT	MAXIMUM FLAME TEMPERATURE °FAHRENHEIT	FLAME SPEED PER SEC.	AUTO IGNITION TEMPERATURE
				LOWER	UPPER					
METHANE	CH ₄	913.1	0.55	5	15	9.56 TO 1	1170°	3484°	0.85	1000
NATURAL GAS		1027	0.6	4.9	15	10.00 TO 1	1170°	3562°	0.99	1000
PROPANE	C ₃ H ₈	2385	1.52	2.10	10.10	23.9 TO 1	898°	3573°	0.95	871

TAKEN FROM FACTORY MUTUAL'S HANDBOOK OF INDUSTRIAL LOSS PREVENTION. CHAPTER 37

SUBJECT:

TOPIC: 11

**SEWAGE TREATMENT
PROCESS CONTROL**

SETTLING TEST

OBJECTIVES:

The trainee will be able to:

1. Demonstrate the settling test.
2. Calculate SVI.

SETTLING TEST

GENERAL

The 30-minute settling test is conducted on mixed liquor to determine the ability of the solids to separate from the liquid in the final clarifier, since the quality of effluent is dependent upon the absence of solids flowing over the effluent weir. The results of the settling test are also used, together with the suspended solids test, to determine sludge volume index. The suspended solids test and settling test should be run on the sample of mixed liquor. This will allow calculation of the Sludge Volume Index (SVI) or the Sludge Density Index (SDI).

The per cent settling rate can be compared for the various days of the week and with other measurements - suspended solids, SVI and per cent sludge solids returned, to provide a record of plant performance and a basis for process control.

APPARATUS

1,000 ml graduated cylinder.

30-minute timer or watch.

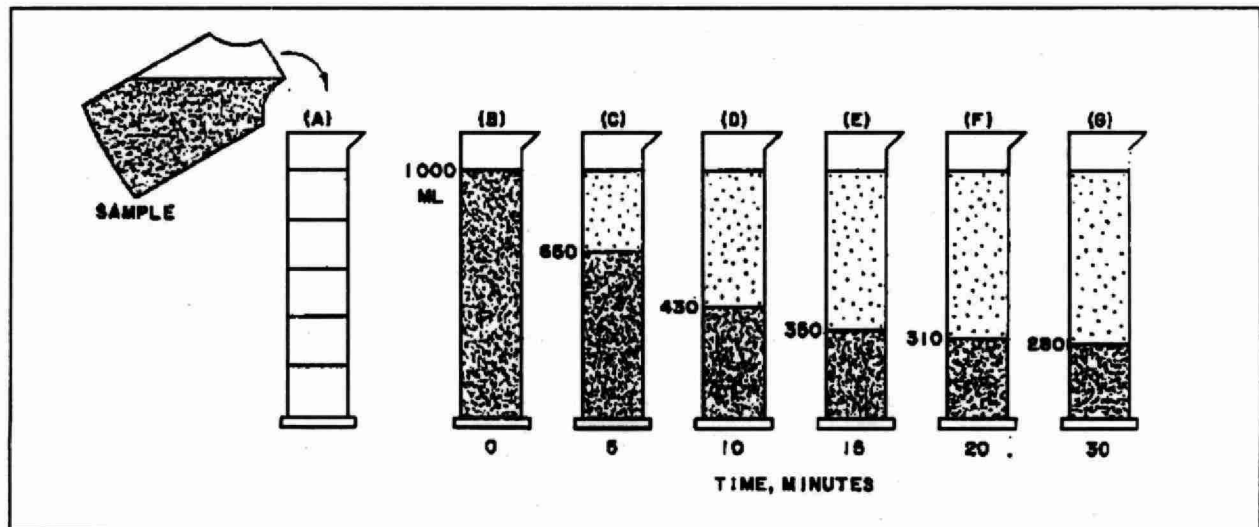


Figure 11-1 Settling of Activated Sludge Solids

PROCEDURE

1. Collect a sample of mixed liquor or return sludge.
2. Gently mix sample and pour into 1,000 ml graduated cylinder. (Vigorous shaking or mixing tends to break up floc and produces slower settling or poorer separation.)
3. Record settling solids at 5-minute intervals on a line graph. See Appendix A.
4. Calculate % settleable solids - e.g. In Figure 11-1, % settleable solids after 15 minutes is

$$\frac{350}{1,000} \times 100 = 35\%$$

5. Plot % settleable solids on graph. See Figure 11-2.

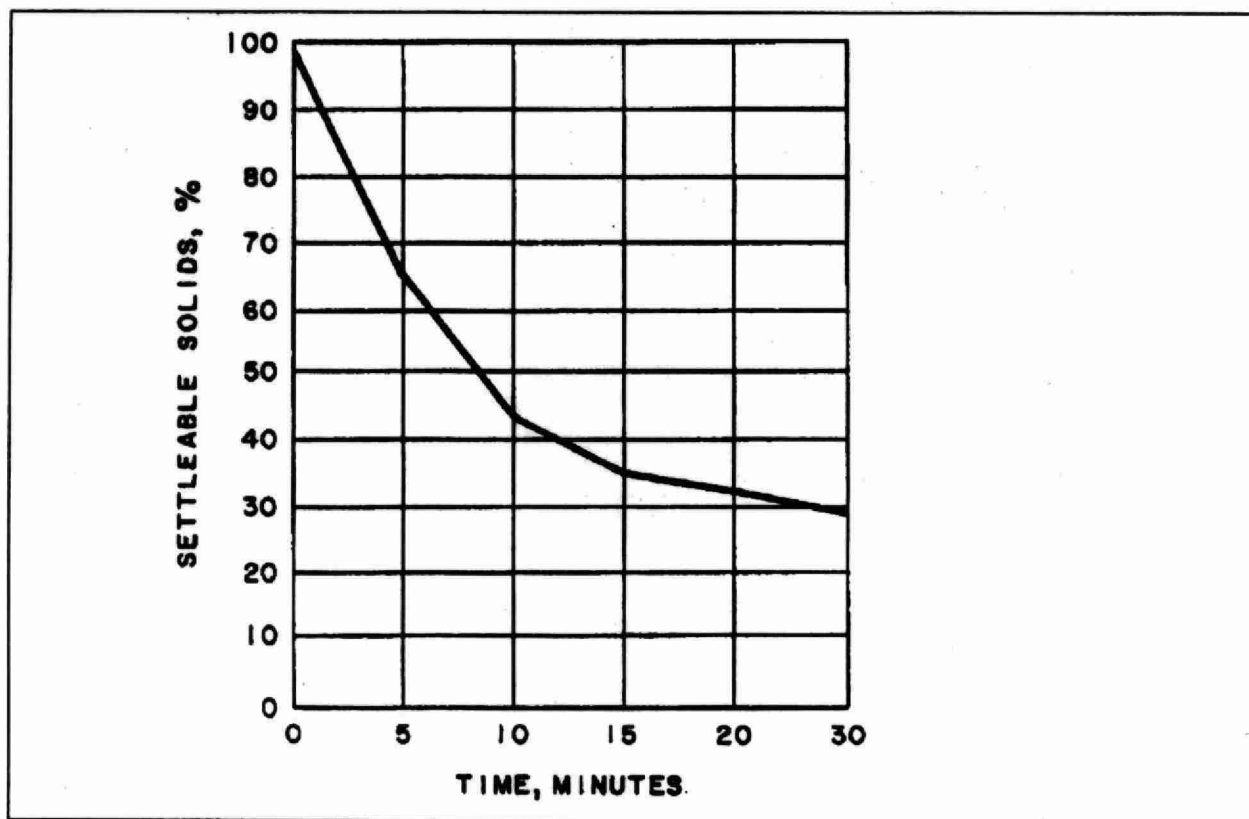


Figure 11-2 Graph Showing Settling of Activated Sludge Solids.

NOTE: If a cold sample of mixed liquor containing a high DO level (typically a winter condition) is allowed to warm up significantly during this test, the sludge may rise due to the desolubilization of gases. The test must then be repeated in a location where the sample will not warm up significantly.

SLUDGE VOLUME INDEX (SVI)

The Sludge Volume Index (SVI) is used to indicate the condition of sludge (aeration solids or suspended solids) for settling in a secondary or final clarifier. The SVI is the **volume** in ml occupied by one gram of mixed liquor suspended solids after 30 minutes of settling. It is a useful test to indicate changes in sludge characteristics. The proper SVI range for a plant is determined at the time when the final effluent is in the **best** condition regarding solids and BOD removals and clarity.

Example

Using a 1,000 ml cylinder, after 30 minutes settled solids = 180 ml or 18%.

Mixed liquor suspended solids = 1,500 mg/l.

Calculations

$$\begin{aligned}\text{Sludge Volume Index (SVI)} &= \frac{\% \text{ Settleable Solids} \times 10,000}{\text{Mixed Liquor Suspended Solids, g/l}} \\ &= \frac{18 \times 10,000}{1,500} \\ &= \frac{1,800}{15} \\ &= 120\end{aligned}$$

SLUDGE DENSITY INDEX (SDI)

The sludge Density Index (SDI) is used in a way similar to the SVI to indicate the settleability of a sludge in a secondary clarifier or effluent. The calculation of the SDI requires the same information as the SVI test.

$$\text{SDI} = 100/\text{SVI}$$

SUBJECT:

TOPIC: 12

PROCESS CONTROL

DISSOLVED OXYGEN ANALYSIS

OBJECTIVES:

The operator will be able to:

1. Demonstrate the method of DO analysis using a DO meter.
2. Calibrate a DO Meter.

DO ANALYSIS

METHODS OF ANALYSIS

The dissolved oxygen level of a sample or contents of a basin or tank can be determined by a membrane type DO meter or the chemical, modified **WINKLER METHOD**.

DO METERS

General

Measurement of the dissolved oxygen (DO) concentration using a DO Meter, which are now common in many plants, is a good substitute for the Sodium Azide Modification of the Winkler Method. Use of a DO Meter offers the following advantages:

1. DO Meters are fast and accurate.
2. Results on DO Meters are unaffected by the floc present in the water.
3. Some DO Meters give direct readings in milligrams per litre (mg/l) or parts per million (ppm) while others give direct readings in per cent saturation. Simply take the meter to the site, put the probe into the liquid to be measured, turn on the meter, allow the meter to stabilize about 1 minute, and read the scale.
4. A direct reading of the liquid temperature is possible when using some DO meters.

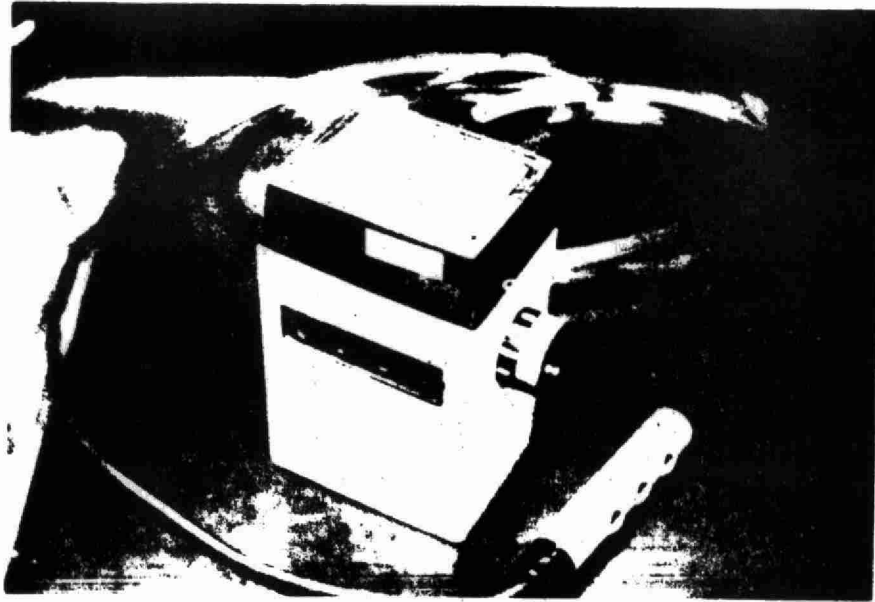


Figure 12-1 E.I.L. DO Meter & Probe
(Readout in per cent saturation)

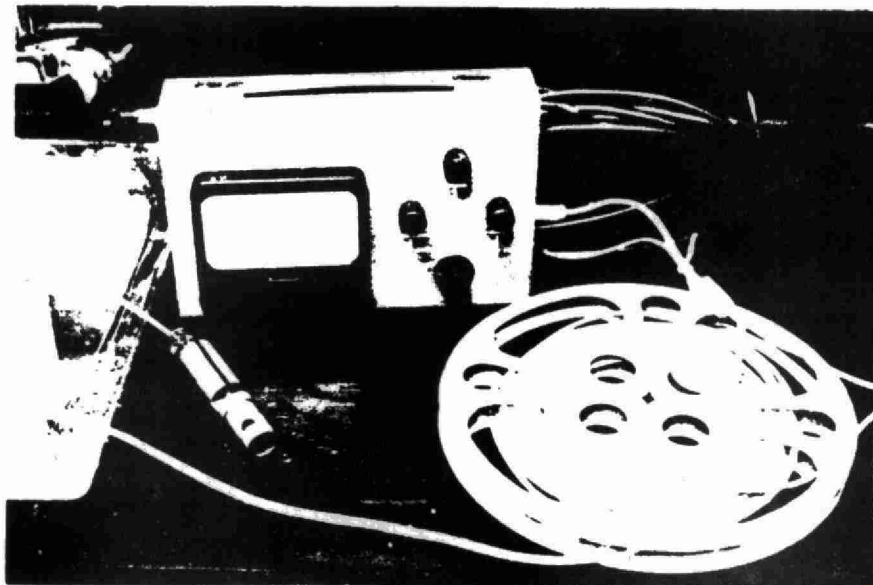


Figure 12-2 Y.S.I. DO Meter & Probe
(Readout in mg. per litre)

The Disadvantages are:

1. Some gaseous reactive compounds, such as sulphides, can interfere by fouling the probe.
2. The membrane area must be cleaned after each use by rinsing with water.
3. The batteries must be kept charged for use of the meter at any time.
4. Recognition of probe failure may be difficult when caused by poisoning or puncture.

Calibration of the DO Meter and Probe

Calibration should be carried out regularly if the DO Meter is to be maintained according to the Manufacturer's Maintenance Manual accompanying the meter. **Calibration should be done at least every two (2) weeks.**

ZERO CHECKING THE DO PROBE

It is advisable to check the response of the probe in a solution that contains zero DO. All membrane type DO probes become sluggish in response at DO levels of less than about 1 mg/l or 10% O₂ saturation. Some probes develop a "memory" of some low level of DO and will not readily read values less than this "memory" which can be as high as 1 mg/l.

To carry out a zero check, proceed as follows:

1. Prepare a zero DO standard solution by making up a 5% solution of sodium sulphite (Na₂SO₃) and adding a small crystal of cobalt chloride (CoCl₂).
2. Immerse the probe into this solution, turn the meter to read D.O., and watch the response of the meter movement. USUALLY the reading rises briefly, then drops sharply, slowing down as the needle approaches zero.
3. When the needle has stopped moving, or after 3 to 5 minutes, expose the probe to a high level of DO (e.g. air or aerated water).
4. Again, immerse the probe into the sodium sulphite solution and observe the meter response.
5. This cycling of the probe from zero DO to high DO should be repeated until the meter will easily read zero in the sodium sulphite solution.

Zero readings may not always be attainable especially with older DO sensors. Readings of 0.1 to 0.2 mg/l are acceptable in that case. Probes that do not approach a zero reading after repeated cyclings may require storing in the sodium sulphite solution overnight.

The "zero" adjust position on most DO meters is designed to electronically adjust the circuit to a simulated zero DO meter reading.

Do not use this adjustment to set the meter reading to zero when the probe is immersed in sodium sulphite solution and the meter switch set to the "read" position.

CALIBRATION - LABORATORY PROCEDURE

After the zero check has been carried out, calibration of the meter is carried out as follows:

1. Take a sample (preferably tap water) which does not contain substances that interfere with either the probe reading or the modified Winkler Method.
2. Divide the sample into two even portions (A&B).
3. Using modified Winkler Method measure the DO in portion (A) of the sample.
4. Using the DO Meter and probe, measure the DO in portion (B) of the sample.
5. Compare the DO values obtained in (3) and (4).
6. If the results coincide, the DO meter is calibrated.
7. If the results do not coincide, adjust the meter according to manufacturer's specifications until it agrees with the modified Winkler Method.

Alternative Procedure for Calibration

A convenient and sufficiently accurate alternative method of calibrating the DO meter and probe is outlined for those not having access to the apparatus required to perform Winkler DO determinations.

It is sometimes difficult to perform steps (3) and (4) of the above method without altering the dissolved oxygen content by accidental aeration of one of the portions. Thus, the following alternative method of calibration may be used:

1. Take approximately 150 ml of distilled water, demineralized water, or tap water that is not excessively high in dissolved solids. Transfer this water to a clean 1 litre stoppered Erlenmeyer flask, or clean stoppered tall cylinder. The water should be at approximately room temperature.
2. Shake this water vigorously for 2 minutes to entrain as much air as possible and cause the sample to become saturated with oxygen.
3. Once saturated, this sample will keep its oxygen saturation level for some period of time unless it becomes contaminated or its temperature is allowed to change drastically.
4. Following is a list * of dissolved oxygen concentrations in mg/l attainable by air saturating a sample of water at various temperatures:

°C	°F	AIR SATURATED WATER DO mg/l
17	62.6	9.7
18	64.4	9.5
19	66.2	9.4
20	68.0	9.2
21	69.8	9.0
22	71.6	8.8
23	73.4	8.7
24	75.2	8.5
25	77.0	8.4
26	78.8	8.2
27	80.6	8.1

* Standard Method, 13th ed, page 480-1.

5. Immerse the DO probe which has been rinsed with tap water into the vessel containing the air saturated water, making sure that all the membrane surface and temperature sensing elements are also immersed.
6. If the probe is not fitted with a means of mechanical agitation, provide the necessary agitation by raising and lowering the probe about one inch two to three times per second, without exposing the membrane surface to the air.

NOTE: The probe will not respond properly unless the sample is moving past the membrane at about 0.5 ft/sec or faster. This velocity is provided by the above means of agitation.

7. Measure the temperature of the water used for calibration and set the temperature compensator dial on the meter to the measured value. Many meters have automatic temperature compensators, which eliminate the need for this adjustment.
8. Select the proper air saturation value from the above table and while agitating the probe adjust the calibration control on the meter to the selected proper DO value.

NOTE: If the meter scale is calibrated in percent oxygen saturation, rather than mg/l or ppm DO, set the meter to 100% on the scale.

9. The meter is now calibrated and ready for use. When taking measurements on a sample stream, be certain to provide the necessary velocity of sample past the probe. For example, aeration sections normally provide sufficient sample velocity, whereas final clarifiers would not.

NOTE: When not in use, always keep the membrane in the tip of the probe from drying by inserting in a flask of water.

WHY? If allowed to dry out, the probe can lose its accuracy until it is reconditioned.

CHEMICAL METHODS

DO Sample Preservation of Mixed Liquor Samples

The DO present in the aeration tank (mixed liquor) is being depleted by the continuous activity of the micro-organisms. To prevent this and to ensure that a correct reading is obtained, 10 ml of copper sulphate-sulphamic acid reagent for each litre of sample should be added (as a preservative) to the sample container **before** taking the sample. This chemical preservative will kill the micro-organisms. The copper sulphate reacts with the alkalinity in the sample, forming a copper hydroxide floc which, as it settles, helps to remove the particles of sludge in the sample. The sulphamic acid, besides killing the bacteria, acts to prevent nitrite oxidation.

To obtain and preserve a sample for DO analysis by the Winkler or Hach Method:

1. Add 10 ml of copper sulphate-sulphamic acid reagent for each litre of sample to be collected in the sampling bottle.
2. Use a tall bottle having a capacity of about 1 quart. An assembly such as the one shown in Figure 12-3 can be used to fill the bottle, ensuring minimum liquid-air contact.
3. Lower the sampling device into the aeration tank in such a way that it will fill without entraining air.
4. Stopper the bottle and mix well by turning it upside down 4 or 5 times.
5. Allow the solids to settle until there is 50% or more clean liquor above the sludge.
6. Siphon the clear liquor into a BOD bottle. Keep the end of the siphon tube at the bottom of the receiving bottle to avoid aerating the sample, and fill until the liquor overflows the bottle. Stopper the bottle.

DO NOT CREATE TURBULENCE WHEN TRANSFERRING LIQUOR INTO THE BOD BOTTLE. THIS LEADS TO AIR ENTRAINMENT.

DO AND BOD SAMPLER ASSEMBLY



WINKLER METHOD

The principle of the Winkler Method is that it releases iodine chemically in proportion to the amount of dissolved oxygen originally present in the sample. Using a standard solution of sodium thiosulphate as a titrant, the amount of iodine and consequently the amount of oxygen present can be determined. It should be noted that the only solution which must be accurately made up (or standardized) is the sodium thiosulphate solution. Preparation of reagents is outlined further on in this topic.

Apparatus Required

1. Buret, capacity 10, 25 or 50 ml, preferably with a Teflon stopcock.
2. Buret support and stand.
3. BOD bottles.
4. Erlenmeyer Flask (200 or 250 ml capacity).
5. Three 10 ml pipets (Serological Pipets) or three 2 ml automatic pipets.
6. One 100 ml graduated cylinder.

Procedure

1. Remove the stopper, and add 2 ml of manganous sulphate solution with the tip of the pipet **slightly below** the surface of the liquid.
2. Using a fresh pipet, add 2 ml of alkaline iodide azide solution, with the tip of the pipet **slightly below** the surface of the liquid.

NOTE: SAFETY PRECAUTIONS

- (i) When transferring solutions, samples etc., by pipette from one bottle to another, use a rubber bulb or other automatic pipetter, **NOT THE MOUTH.**
 - (ii) Use safety glasses for shielding against possible splashing.
 - (iii) Wear protective clothing (such as a lab coat, for example) to prevent damage to clothing.
3. Make sure that no air bubbles are trapped by tapping the side of the bottle near the shoulder with the stopper. Replace the stopper.
 4. Mix thoroughly by turning upside down several times. Do this over a sink since there will be liquid in the seal around the stopper.
 5. Allow to settle about half-way. Mix again by inverting and allow to settle a second time. (After addition of the manganous sulphate solution and the alkaline-iodide-azide solution, the samples can be left, if necessary, to complete other work.)

NOTE: When the alkaline-azide-iodide reagent is added, a dense precipitate will form. If this precipitate is pure white, there is no oxygen present; if the precipitate is amber-coloured, there is oxygen present.

6. Remove the stopper and add 2 ml of concentrated sulphuric acid above the liquid surface, letting the acid run down inside the neck of the bottle. Use another pipet for this reagent.

7. Replace stopper and mix by inverting. Do this over a sink. The amber solution of free iodine produced is not stable and should be titrated immediately.
8. Measure 100 ml of the solution in a 100 ml graduated cylinder. Transfer it to an Erlenmeyer Flask.
9. Fill the buret to the zero mark with 0.025N sodium thiosulphate.
10. Add sodium thiosulphate from the buret at a fast rate (steady stream) while mixing the contents of the flask by swirling. Slow down the rate of titrant addition as a pale yellow colour is reached.
11. When the solution is pale yellow, add about 1/2 ml of starch solution (an eyedropper-full). The sample will turn blue and the titration is continued, adding the sodium thiosulphate dropwise until the solution is colourless. This is the **END POINT**.

NOTE: If the colour does not appear when the starch indicator is added, the titration has been carried too far and must be repeated. If the solution turns brownish black, the starch indicator has been added too early and the procedure must be repeated.

12. Record the amount of sodium thiosulphate solution used in ml.
13. When disposing of the sample (both the titrated portion and that remaining in the BOD bottle), leave the water running in the sink to thoroughly flush the acid down the drain.

Calculation

The concentration of dissolved oxygen in the original sample is equal to twice the number of ml of sodium thiosulphate used when 100 ml of solution are titrated.

e.g. The titration required 2.3 ml of sodium thiosulphate solution; therefore, the dissolved oxygen concentration was $2 \times 2.3 = 4.6$ mg/l.

THE HACH DO KIT

This method is essentially a Winkler dissolved oxygen determination with all chemicals supplied in kit form.

1. It is a small, completely self-contained kit.
2. It is easy to transport.
3. It is easy to use (see procedure).
4. It is a modification of the Sodium Azide modification of the Winkler Test.
5. The Hach DO Kit is suited for plant applications. All the chemicals are contained in small plastic pillows, with the exception of the titrating solution. This keeps them uncontaminated and they will last a long period of time. The titrating solution, which is phenylarsene oxide, is very stable. By avoiding contamination, and keeping it well stoppered, it will remain stable for an exceptionally long period of time.

NOTE: Follow the sampling and analytical instructions carefully to produce results comparable to the Winkler method.

Procedure Using the Hach DO Kit

1. Fill the DO sample bottle with the water to be tested by allowing the water to overflow the bottle for 2 or 3 volumes. Be certain there are no air bubbles in the bottle.
2. Add the contents of one Dissolved Oxygen I Powder Pillow (Manganous Sulphate) and one Dissolved Oxygen II Powder Pillow (Alkaline Iodide-Azide). Stopper in a manner to keep out air. Shake to mix and allow the floc that is formed to settle half-way in the bottle.

3. Remove the stopper and add the contents of one Dissolved Oxygen III Powder Pillow (Dry Acid). Re- stopper and shake to mix. The floc will dissolve and a yellow colour will develop if oxygen is present. **This is the prepared sample.**
4. Fill the sample measuring tube level full with prepared sample and pour it into the 1 oz. titrating vial.
5. Using the dropper provided, add PAO Solution, to mix, and counting each drop. The titrating end point is reached when the sample has turned colourless. Use starch indicator if available to obtain sharper end point. The mg/l Dissolved Oxygen is equal to the number of drops used.

NOTE: It is a bit tricky to stopper the DO sample bottle without getting an air bubble trapped in the bottle. To avoid the air bubble, tip the sample bottle slightly, and insert the stopper with a quick thrust. This will force the air bubbles out.

All the above directions are supplied with the kits and include a procedure for Low Range Dissolved Oxygen where each drop of PAO is equal to 0.2 mg/l.

PREPARATION OF REAGENTS

Copper Sulphate - Sulphamic Acid

1. Dissolved **approximately** 32 gm of technical grade sulphamic acid ($\text{NH}_3\text{SO}_2\text{OH}$) without heating in about 475 ml of tap or distilled water.
2. Dissolve 50 gm of technical grade copper sulphate crystals ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) in about 400 ml of tap water.
3. Mix the two solutions.
4. Add **approximately** 25 ml of concentrated acetic acid.

Manganous Sulphate Solution

1. Weigh out about 480 gm of manganous sulphate ($\text{MnSO}_4 \cdot 4\text{H}_2\text{O}$).
2. Dissolve in 400 to 600 ml of distilled water.
3. Add distilled water to make up volume to 1 litre.

NOTE: Filtration of the solution as recommended in "Standard Methods" may be necessary if there is an oily film on top, or if there is evidence of insoluble black matter. The solution, using reagent grade manganous sulphate, is a clear pink colour.

Alkaline Iodide-Azide Solution

1. Weight about 500 gm of sodium hydroxide (or about 700 gm of potassium hydroxide).
2. Dissolve the sodium hydroxide in 500 to 600 ml of distilled water in a Pyrex beaker, cooling the solution in a water or ice bath.
3. Weigh about 150 gm of potassium iodide (KI) (or 135 gm of sodium iodide, NaI).
4. Dissolve the potassium iodide in about 200 to 300 ml of distilled water. When the sodium hydroxide solution is cool, add the potassium iodide solution to it slowly while mixing.
5. Dissolve about 10 gm of sodium azide (NaN_3) in 50 ml of distilled water.
CAUTION: Sodium azide is unstable and in acidic solution could be explosive and also releases toxic fumes.
6. Add the sodium azide solution to the cooled alkaline iodide solution.
7. Dilute with distilled water to 1 litre.

Sulphuric Acid

Use concentrated reagent grade sulphuric acid. Handle it carefully because it is a strong acid. It will "burn" holes in cloth, especially cotton, and can cause severe irritation of the skin.

NOTE: Always add acid to water - never water to acid.

Starch "Solution"

1. Make a thin paste of 3 gm of starch (soluble, potato, arrowroot, etc.) with a small amount of distilled water.
2. Pour into 500 ml of boiling distilled water.
3. Add 1.25 gm/l of salicylic acid for preservation.
4. Allow to cool and settle overnight.
5. Decant, saving the clear supernatant.

Sodium Thiosulphate Solution (0.025N)

NOTE: 0.025N Sodium Thiosulphate Solution may be purchased from some chemical supply houses, or prepared as follows:

1. Weigh out, as accurately as possible, 6.20 gm of sodium thiosulphate crystals ($\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$). **Do not dry before weighing.**
2. Dissolve in distilled water and make up to 1.00 litre with distilled water.
3. Add about 5 ml chloroform or about 0.4 grams of sodium hydroxide pellets as a preservative.

NOTE: If this solution is to be used for plant dissolved oxygen tests only, it will be sufficiently accurate. However, if it is to be used in BOD determinations, it should be standardized against 0.025N Potassium Dichromat (Reagent g). Because the sodium thiosulphate solution is unstable, it should be replaced every month or standardized weekly if it is used for BODs.

Potassium Dichromat Solution (0.025N)

NOTE: 0.025N Potassium Dichromat Solution may be purchased from some chemical supply houses, or prepared as follows:

1. Put about 5 gm of reagent grade potassium dichromat ($K_2Cr_2O_7$) in a 50 ml beaker or a weighing bottle.
2. Dry the potassium dichromat at $103^{\circ}C$ overnight in the oven.
3. Cool in desiccator.
4. Weigh out exactly 1.226 gm, transferring it to a 1 litre volumetric flask.
5. Dissolve in distilled water; make up to the 1 litre mark.
6. Transfer the solution to a reagent bottle for storage. No solutions should be stored in volumetric flasks.
7. This solution is stable and will not have to be replaced unless it becomes contaminated or is allowed to evaporate significantly.

SUBJECT:

TOPIC: 13

SEWAGE TREATMENT PROCESS CONTROL

**CHLORINE TESTING
PROCEDURES**

- DPD METHOD
- ORTHOTOLIDINE TEST
- AMPEROMETRIC

OBJECTIVES:

The trainee will be able to:

1. Demonstrate and carry out the procedures for determining the chlorine residual using the DPD method with the Nesslerizer and Comparator.
2. Describe the principle of operation of the Amperometric Titrator and/or carry out chlorine analysis on such an instrument.

CHLORINE TESTING PROCEDURES

DPD METHOD

Principle of the Method

Research in chlorine chemistry has resulted in the development of a very simple procedure for the determination of total residual. With the new method, differentiation between the combined forms of chlorine is also possible using the DPD indicator. The test is accurate and, when properly used, it can be an excellent aid to the control of chlorine residual at a wastewater treatment plant.

A good feature of the Lovibond Comparator method lies in its use of compressed tablets which are convenient to handle and more stable than the DPD solution. In a recent investigation by the Water Research Association, this method was judged the **BEST COLORIMETRIC METHOD** for the measurement of total residual chlorine in water.

Equipment and Reagents Required

1. DPD tablets for Comparator and Nesslerizer No. 1 & 3 together for total chlorine residual, or No. 4 which replaces both No. 1 and 3.
2. **Comparator with Standard Lovibond Discs**
 - a) 3/40A disc covers the range 0.1 to 1.0 mg/l chlorine.
 - b) 3/40B disc covers the range 0.2 to 4.0 mg/l chlorine.

These discs require 13.5 mm cells or test tubes. A dulling screen must be used.

3. **Nesslerizer with Disc**

NDP covers the range 0.05 to 0.5 mg/l. This disc must be used with a dulling screen and 50 ml tubes.

Procedure - Total Chlorine Residual

1. Comparator

- a) Place a 13.5 mm cell or test tube containing sample only in the left hand compartment, behind the colour standards of the disc.
- b) Rinse a similar cell with the sample, and fill the cell or tube up to the mark with it.
- c) Into this cell or tube drop one No. 1 and one No. 3 tablet (or one No. 4 tablet, which is No. 1 and No. 3 combined).
- d) Allow tablets (or tablet) to disintegrate until effervescence ceases.
- e) **Mix rapidly** to dissolve the remains of the tablet.
- f) Place the cell in the right hand compartment of the Comparator.
- g) **After 2 minutes**, match the cells by holding the Comparator facing a good source of diffused north daylight and **revolve this disc until the correct standard found. NEVER LOOK INTO THE SUN.**
- h) The figure shown in the indicator window represents mg/l of **total chlorine residual** present in the sample.

2. Nesslerizer

Follow exactly the same procedure for the Comparator, with the following exceptions:

- a) Use 50 ml instead of 10 ml.
- b) Use special Nesslerizer DPD tablets.

NOTE:

It must be emphasized that the readings obtained by means of the B.D.H. Lovibond Nesslerizer and disc are only accurate provided that Nesslerizer glass is used which conforms to the specification employed when the discs are calibrated; namely, that the 50 ml calibration mark shall fall at a height of 113 \pm 3 mm, measured internally.

AMPEROMETRIC TITRATION METHOD

General

The most accurate methods of measuring total chlorine residuals is through oxidation-reduction titration procedures. Such methods require the use of internal indicators or electro-metric devices employing a suitable electrode system to show when reactions are completed. Amperometric titrators employing rotating platinum electrodes have been developed for such purposes. (See Figure 11-1, page 11-5)

Titration - Principle of Operation

Titration is a method used to determine the concentration of a substance in a solution. This is accomplished by adding the smallest amount of a reagent (of known concentration) required to cause a neutralizing effect, in reaction with a known volume of the test solution. A graduated vessel (or burette) is used to add the reagent to the known volume of test solution until the chemical reaction between the two is completed. The point of completion is indicated by either (a) adding an indicator dye and watching for a change in its odour or (b) stopping at a predetermined end point on a pH meter or micrometer.

A direct current potential is impressed across two nodal metal electrodes immersed in a measuring cell containing the sample of the solution to be tested. Any flow of current between the electrodes is directly proportional to the quantity of halogen (such as chlorine, bromine, or iodine) in the sample. The presence of a current is indicated on a micrometer at the top of the instrument.

A reagent (also called a titrant), phenylarsene oxide, is added in small doses to the sample, and reacts chemically with the chlorine present in the solution, thereby neutralizing a portion of the chlorine. As more titrant is added, more chlorine is "removed", causing the current flowing between the electrodes to diminish as indicated by the micrometer pointer moving down the scale. Finally, sufficient titrant is added to react with all the chlorine, and no further decrease in current is possible. This is called the **end point**.

The amount of chlorine residual present in the test solution is determined by noting the number of millilitres of titrant used to attain the end point. Then:

$$\text{mg/l of chlorine} = \text{mls of titrant that have been used.}$$

Procedure

1. Switch on

Set the rocker switch to the TOTAL position.

2. Filling the Burette

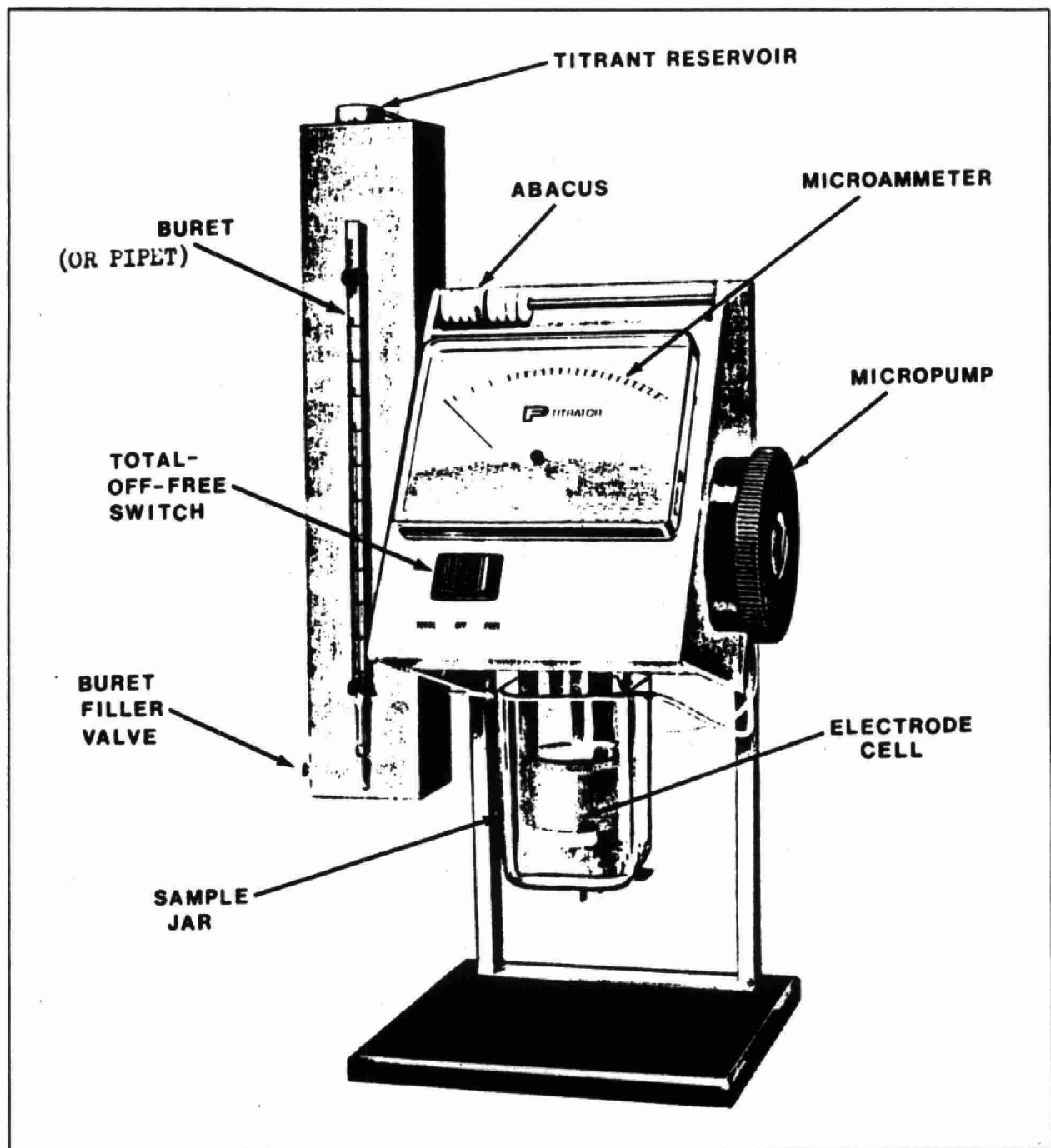
Make sure the titrant (phenylarsene oxide solution) fills to the zero mark.

3. Titration of Total Chlorine Residual

- a) Fill the solution jar with 200 ml of sample.
- b) Add 1 ml Potassium Iodide Solution followed by 1 ml pH4 buffer solution IN THAT ORDER.
- c) Fill the microburette with the titrant (phenylarsene oxide solution) to the zero mark.
- d) Titrate by adding phenylarsene oxide solution and observe current changes on the micrometer. As long as addition of phenylarsene oxide produces a definite decrease in current, free chlorine residual is present.
- e) The end point is just passed when a very small increment of phenylarsene oxide no longer causes a decrease in current.
- f) The burette is then read and the last increment of titrating solution is subtracted from the reading to give a value representing the total chlorine residual.

Figure 13-1

AMPEROMETRIC TITRATOR
(Courtesy Fischer & Porter)



GLOSSARY OF TERMS

*The following definitions are intended
only as aids in the study of this manual.*

absorption -

The taking up of one substance into the body of another.

activated sludge -

Sludge floc produced in raw or settled wastewater by the growth of zooglycal bacteria and other organisms in the presence of dissolved oxygen and accumulated in sufficient concentration by returning floc previously formed.

adsorption -

- (1) The adherence of a gas, liquid, or dissolved material on the surface of a solid.
- (2) A change in concentration of gas or solute at the interface of a two-phase system. Should not be confused with absorption.

aeration -

- (1) The bringing about of intimate contact between air and a liquid by one or more of the following methods:
 - a. spraying the liquid in the air,
 - b. bubbling air through the liquid,
 - c. agitating the liquid to promote surface absorption of air.
- (2) The supplying of air to confined spaces under nappes, downstream from gates in conduits, etc. to relieve low pressures and to replenish air entrained and removed from such confined spaces by flowing water.
- (3) Relief of the effects of cavitation by admitting air to the section affected.

aerobic -

Requiring, or not destroyed by, the presence of free elemental oxygen.

algae -

Tiny plants, usually living in water and often green.

alkaline -

A condition which will raise the pH in water or wastewater higher than 7.

bacteria -

Single-celled microscopic plants living in soil, water, organic matter, or the bodies of plants and animals.

baffle -

A device to turn aside, check, or regulate flow.

barminutor -

Trade name for a shredding device.

bar screen -

A rack made of parallel bars for removing coarse materials in the wastewater passing between them.

BOD -

Biochemical Oxygen Demand. A measure of the oxygen used in decomposing organic matter.

bulking -

Bulking occurs in activated sludge plants when the sludge becomes too light and will not settle properly.

centrifuge -

A machine that separates solids from wastewater in a spinning motion.

chemical oxygen demand -

A measure of the oxygen-consuming capacity of inorganic and organic matter present in water or wastewater. It is expressed as the amount of oxygen consumed from a chemical oxidant in a specific test. It does not differentiate between stable and unstable organic matter and thus does not necessarily correlate with biochemical oxygen demand. Also known as OC and DOC, oxygen consumed and dichromate oxygen consumed, respectively.

chlorine demand -

The difference between the amount of chlorine added to a water or wastewater and the amount of chlorine residual left after a certain length of time.

clarifier -

A unit of which the primary purpose is to secure clarification. Usually applied to sedimentation tanks or basins.

coagulants -

In water and wastewater, chemicals used to thicken finely divided suspended solids into groups for easy removal.

coagulation -

In water and wastewater treatment, the destabilization and initial aggregation of colloidal and finely divided suspended matter by the addition of a floc-forming chemical or by biological processes.

colloidal -

Finely divided solids which will not settle but may be removed by coagulation or biochemical action or membrane filtration.

comminutor -

A shredding device used in pretreatment.

cross flight -

Wooden scraper for moving sludge and scum in a rectangular clarifier.

decomposition -

Generally aerobic processes that convert unstable materials into more stable forms by chemical or biological action. Waste treatment encourages decay in a controlled situation in order that the material may be disposed of in a stable form. When organic matter decays under anaerobic conditions (putrefaction), undesirable odours are produced. In aerobic processes, the odours are much less objectionable than those produced by anaerobic decomposition.

detention time -

The length of time that wastewater is held in a unit for treatment.

detritor -

Equipment used in pretreatment to remove heavy minerals such as grit, and other coarse debris carried in water and wastewater.

diffuser -

A device for distributing tiny air bubbles throughout a liquid, such as wastewater.

digestion -

The biological decomposition of organic matter to a more stable form.

dissolved oxygen -

Atmospheric oxygen dissolved in water or wastewater, usually abbreviated DO.

effluent -

In wastewater treatment, wastewater or other liquid, partially or completely treated or in its natural state, flowing out of a reservoir, basin, treatment plant, or industrial treatment plant, or part thereof.

elutriate -

To purify, separate, or remove by washing.

endogenous -

A diminished level of respiration in which materials previously stored by the cell are oxidized.

enzyme -

A protein that promotes a chemical reaction, enabling it to continue at body temperature.

filamentous bacteria -

These bacteria develop where carbohydrates are present and where there is low dissolved oxygen content. The result is bulking and poor settling. These organisms grow in a thread or filamentous form.

flights -

Wooden scrapers mounted on parallel chains to move sludge to a hopper at the end of a rectangular clarifier.

floc -

Small gelatinous masses formed in a liquid by the reaction of a coagulant added thereto, through biochemical processes, or by agglomeration.

flocculation -

The collection of coagulated suspended solids into a mass by gentle stirring.

flotation -

The raising of suspended matter to the surface of wastewater in a tank for removal by skimming.

fungi -

Small non-chlorophyll-bearing plants which lack roots, stems, or leaves, which occur (among other places) in water, wastewater, or wastewater effluents and grow best in the absence of light. Their decomposition after death may cause disagreeable tastes and odours in water; in some wastewater treatment processes they are helpful and in others they are detrimental.

Imhoff tank -

A wastewater treatment tank with two chambers for sedimentation and sludge digestion.

influent -

Water, wastewater, or other liquid flowing into a reservoir, basin, or treatment plant, or any unit thereof.

inorganic -

Chemical substances of mineral origin, or more correctly, not of basically carbon structure.

metabolize -

To perform the chemical changes in organic cells, providing energy for growth and activity.

microbes -

Microscopic organisms, especially pathogenic bacterium.

micro-organisms -

Minute organisms, either plant or animal, invisible or barely visible to the naked eye.

mixed liquor -

A mixture of activated sludge and organic matter undergoing treatment in the aeration tank.

nitrification -

- (1) The conversion of nitrogenous matter into nitrates by bacteria.
- (2) The treatment of a material with nitric acid.

nutrient -

Food for the growth of organisms.

organic -

Chemical substances of animal or vegetable origin, or more correctly, of basically carbon structure, comprising compounds consisting of hydrocarbons and their derivatives.

oxidation -

The act of combining with oxygen; any reaction which involves the loss of electrons from an atom.

oxygenation capacity -

In treatment processes, a measure of the ability of an aerator to supply oxygen to a liquid.

Parshall Flume -

A device used to measure liquid flow in a channel.

pH -

The measure of the acid/alkaline balance, expressed on a scale of 0 to 14, with 7 being neutral; 7 to 0 increasing acidity, and 7 to 14 increasing alkalinity.

preaeration -

A method of preparing wastewater for treatment by aeration to remove gases, add oxygen, float grease, etc.

protozoa -

Unicellular microscopic animals, protozoa consume bacteria, thus promoting the growth of new bacteria. They feed on the surface of biological floc and on dispersed bacteria, which results in a clear effluent. The presence of protozoa indicates that there is sufficient dissolved oxygen and a lack of toxic elements. There are two basic forms:

Free-swimming ciliate protozoa - Fine hairs allow these ciliates to swim rapidly. They have a high energy level and require a large quantity of organic food.

Stalked ciliate protozoa - Normally found in high-rate systems in equal numbers with the free-swimming ciliates, they attach themselves by their stalks to solid particles.

putrescible -

- (1) The relative tendency of organic matter to undergo decomposition in the absence of oxygen.
- (2) The susceptibility of wastewaters, effluent, or sludge to putrefaction.
- (3) In water or wastewater analysis, the stability of a polluted water or raw or partially treated wastewater.

retention time (or period) -

The theoretical time required to displace the contents of a tank or unit at a given rate of discharge (volume divided by rate of feed). Also called detention time.

rotifers -

Multicellular microscopic animals which feed on bacteria and protozoa, rotifers exist only in the presence of dissolved oxygen and are an indication of a high degree of treatment. They are normally found in extended aeration systems.

stabilize -

To convert to a form that resists change. Organic material is stabilized by bacteria which convert the material to gases and other relatively inert substances. Stabilized organic material generally will not give off obnoxious odours.

sedimentation -

Settling or clarification; the process of allowing solids in water and sewage to sink to the bottom for easy removal.

supernatant -

The liquid standing above a sediment or precipitate.

suspended solids -

- (1) Solids that either float on the surface of, or are in suspension in, water, wastewater, or other liquids, and which are largely removable by laboratory filtering.
- (2) The quantity of material removed from wastewater in a laboratory test, as prescribed in "Standard Methods for the Examination of Water and Wastewater" and referred to as non-filterable residue.

total solids -

The sum of dissolved and undissolved constituents in water or wastewater, usually stated in milligrams per litre.

turbidity -

A condition in water caused by suspended matter; murkiness.

volatile solids -

The quantity of solids in water, wastewater, or other liquids, lost on ignition of the dry solids at 550°C.

weir -

A dam or enclosure in water or wastewater used to raise the water level or change the direction of its flow; with notches or a crest, it measures the flow.



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